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Colin Bevan Rees
1914—1956

All those who knew him, or knew of his work on the zooplankton, are the poorer for the sadly premature death of Colin Rees, on 2. September 1956. His attendance at the Council Meeting in 1955 will be remembered by members of the Plankton Committee and many others. From his first entry into this field, he proved an energetic and original worker — devoted to his subject, yet unspecialized enough to have a healthy interest in most other aspects of life, from economics to art. He was indeed a water-colour artist of considerable merit and several of his pictures were shown in Edinburgh's major galleries. Whatever he did was done with the greatest enthusiasm.

He was born on 25. October 1914 at Pontardawe in Glamorgan, and was educated at Pontardawe Grammar School and then at University College, Cardiff. He subsequently graduated with first-class Honours in Zoology, and his first research, under Professor TATTERSALL, was concerned with the ecology of the Severn Estuary. In 1937 he was appointed a member of the staff of the Department of Zoology and Oceanography, under Professor A. C. HARDY, in the University (then College) of Hull, to work in the Department's newly-opened extension at Leith. There he worked on material collected with Continuous Plankton Recorders over the whole North Sea and adjacent waters, at first specializing on the copepods. His first paper of several in the *Hull Bulletins of Marine Ecology* was written jointly with C. E. LUCAS and N. B. MARSHALL, on the plankton of the Faroe-Shetland Channel in 1939, and his second, with K. M. RAE, on the North Sea copepods during 1938 and 1939. The second paper illustrated for the first time the main features of the copepod distribution month by month and particularly the gradual procession of the "indicator" organisms, *Metridia* and *Candacia*, from the north-western North Sea down towards the Dogger Bank region between August and December. This preliminary work led to a special interest in the copepod *Calanus*, for which he later demonstrated the widespread sequence in the North Sea of four broods during the year, with a principal one in the spring; he also convinced us of the undoubted existence of the two forms of *Calanus—finmarchicus* and *helgolandicus*.

The recent world war took him away from biological research; like a number of British biologists, he served as a radar officer, attaining the rank of Captain. He returned to the Leith Laboratory (now the Edinburgh Oceanographic Laboratory of the Scottish Marine Biological Association) to help with the Continuous Plankton Recorder survey after the war. Then, despite his continued interest in the copepods, he began to develop a special interest in the planktonic larvae of bottom-living adults. This work produced a sequence of papers, on the distribution, movement, and seasonal variation of these larvae over the North Sea during the years after the war. Perhaps the accounts of the decapods proved the least difficult, since their systematics had been well worked out. There were a few problems for him concerning the echinoderms, because of the difficulties always met when identifying Recorder material, but he was able to add to our knowledge of the structural development of their larvae. Undoubtedly, however, his major contribution lay in the field of the lamellibranch larvae, of which his first paper described no fewer then seventy-seven. Well illustrated by photographs and diagrams, it has been of assistance to all other

workers in the field. It was based on subtle but real distinctions in the shape and texture of the larval shells and more precisely on the structure of their hinges. On this foundation, he was then able to provide a detailed account of their various distributions and periodicities, together with evidence of their relationship to some of the known swirls or eddy regions in the North Sea. For this and other work he received the D.Sc. degree from his University in 1951.

He also showed how, despite a generally diffuse distribution, the decapod larvae were by far the dominant forms in the south-western North Sea, the echinoderm larvae in the south-eastern, and the lamellibranch larvae in the centre and the north. As the material available to him and his extensive knowledge of it grew, he acquired quite clear ideas of some of the movements undergone by the larvae during their periods of drifting and in this his ability to inter-relate the data for a number of forms was particularly valuable. For example, he was able to show the apparent drift of mussel larvae and associated forms, including copepods, in narrow bands or streaks, for considerable distances; this he associated with the variable movement of "mixed" water from the north-western North Sea well into the central region. Nor had he forsaken *Calanus* and its varieties for these interests, for he was just able to finish another paper on their distribution, this time in the North Sea and adjacent Atlantic Ocean. He was, indeed, working most energetically in several directions when illness suddenly overtook him, and had he lived, he would undoubtedly have added considerably more to our knowledge of plankton ecology in these waters. There remains a mass of data, as well as his copious notes on them, which we must all hope will be written up in due course.

The sympathy of all his friends goes to his two young children and to his widow, who was also a scientist and with whom he shared a deep interest in painting. He will always be remembered for his enthusiastic and critical conversation and for his very good company.

C. E. Lucas

We announce with regret the death on 18. January 1957 of Vice-Admiral John Dodd Nares, Distinguished Service Order, Grand Officier de l'Ordre de Saint-Charles, Royal British Navy, a member of the Directing Committee of the International Hydrographic Bureau, Monaco, since 1932.

The Direct Estimation of Ammonia in Sea Water, with Notes on Nitrate, Copper, Zinc, and Sugars

By

W. R. G. Atkins

THE following notes deal with a number of problems which had been listed for attack, but which, for various reasons, could not be examined save in a preliminary manner. These beginnings are now set forth in the hope that other workers may find something useful in them.

The Estimation of Ammonia

BARNES (1955, a & b) has reviewed the methods available, so it need only be remarked that a quick method not requiring distillation or precipitation was badly wanted for work on ammonia in sea water. That introduced by KRUSE and MELLON (1952) for industrial wastes was tried and seems to have advantages. A sample containing ammonium salts gives a purple colour when treated with chloramine T and then with a pyridine pyrazolone reagent. This can be extracted with carbon tetrachloride and the colour matched, or it can be examined in a spectrophotometer at 450 mμ. Even with a 1 cm. cell as little as 0·025 parts per million can be determined. The procedure is as follows: —

The pH of a 50 ml. sea-water sample is adjusted to about 3·7 because the absorbance of light by the purple is greatest at around pH 3·2 to 3·8. Accordingly one adds 1·5 ml. of N/10 H_2SO_4. To this, 10 ml. of buffer solution is added; with WALPOLE's acetic-acid sodium-acetate series, N/5 acid and acetate in the proportions by volume of 9 to 1 give pH 3·7. Then add 1 ml. of 2·7% chloramine T, and 90 seconds later add 30 ml. of the pyridine pyrazolone reagent. After about 60 seconds for colour development, extract by shaking with 25 or 50 ml. of pure CCl_4 and measure absorbance of the latter at 450 mμ. The reagent is prepared by dissolving 0·63 g. of recrystallized 3-methyl-1-phenyl-5-pyrazolone in 250 ml. of water at 75°C., and cooling to room temperature. Then to 5 volumes of this, add 1 volume

of colourless pure pyridine containing 0·1% of bis (3-methyl-1-phenyl-5-pyrazolone). The pyridine pyrazolone reagent should be mixed only a few hours before use and the bispyrazolone in pyridine should be freshly prepared. It is convenient to dilute the N/10 acid with one-third of its volume of water and to take 2·0 ml., and to dilute the chloramine T to one-half strength and take 2·0 ml. also. One then has: — (1) Sample, 50 ml.; (2) Acid, 2 ml.; (3) Buffer, 10 ml.; (4) Chloramine T, 2 ml. standing 90 seconds; (5) Pyrazolone reagent, 30 ml. standing 60 seconds, and (6) Carbon tetrachloride, 25 ml. Shake violently for 2 minutes and allow to settle in a separating funnel. The total volume is 119 ml.

To start with, it is advisable to test the reagents and procedure by comparing three samples distilled water (which need not be acidified but 1·5 ml. more water should be added), sea water, and sea water with 1·0 ml. of standard ammonium chloride 1·573 g. made up to 1 litre, and diluted to one-tenth for use, so that each millilitre contains 50 μg.

Note on Nitrate Estimation

In his review Barnes comments "It is not clear why it (the diphenyl benzidine method, 1932) has not been more used, particularly as the blue colour, unlike that produced with the strychnine reagent, is stable to light". One reason is that several workers failed to realize how hard it is to mix the viscous sulphuric acid solutions; also when suspended matter was not removed properly, allowing the acid and water to stand till cool before adding the reagent resulted in a reduction in the nitrate. As shown in Table 3 (1932), six tubes, each with centrifuged sea water containing 72 mg. per m^3. of nitrate nitrogen, (with the first tube in the row taken as 100·0) gave as a mean value 101·2, with extremes 97·0 and 103·3; the volume of sea water was only 2·50 ml. measured without an automatic pipette, so the consistency is good. The method was used by Gessner (1934), Elster and Gessner (1935), Wattenberg (1937), Riley (1939), and Black and Dewar (1949).

It has now been recommended (1954) that in order to minimize loss from the action of organic matter and to facilitate mixing, it is better to add the diphenyl benzidine in 7·5 ml. of sulphuric acid and to add 2·5 ml. of sea water with stirring.

The various reagents used to obtain a delicate reaction for nitrate have all necessitated the use of strong sulphuric acid, which is an objection, especially at sea. An ideal method would be to reduce nitrate to nitrite and to use the Griess-Ilosvay reagent. There are, however, indications that with a quartz mercury arc the quantitative decomposition of nitrate to nitrite only may be accomplished. Warburg (1918) showed that in the presence of potassium nitrate, potassium iodide, and sulphuric acid, NO and iodine were set free. In the presence of oxygen, NO_2 was produced and the estimation effected by the Griess-Ilosvay reaction.

Holmes (1926) was unable to detect any loss of nitrite from a 2·6 N solution of ammonium nitrite exposed in a quartz vessel for six hours to a 110 v. quartz mercury arc at 8–16 cm.; but Mukherji and Dhar (1925) had found that nitrous acid can thus be decomposed.

Gillam and Morton (1927) found that nitrate yielded nitrite when buffered at pH 9·4 and exposed.

Vogels (1936) studied the effects of various catalysts such as manganous hydroxide and lactate, and considered that the mercury-arc lines at and around 365 mμ were the most important. Cultrera (1936) found the reduction was also effected by sunlight. The method appears worth studying and if traces of ammonia were also produced such action could be eliminated by surrounding the tubular mercury arc with a solution of sodium nitrite to absorb the lines responsible. Nitrate shows an absorption maximum at 302 mμ, which was used by Dolance and Healy (1945) for measurements to estimate nitrate in plating baths in the presence of nitrites, but the test is not delicate enough for sea water. The important point in preventing the reduction to ammonia appears to be the maintenance of an alkaline reaction, over pH 9.

Note on Estimation of Copper

Sodium diethyl-dithiocarbamate was introduced (Atkins, 1932) for use in sea water, Delépine (1908), and later Callan and Henderson (1929), having pointed out its delicacy as a test for copper. Following the latter, Atkins (1933) used the extraction method and found that carbon tetrachloride had advantages, being heavier than water and less soluble than chloroform. Chow and Thompson (1952), after a very careful study, selected xylene as their liquid, but this involves sucking off the xylene or draining off the larger aqueous volume. They found that in a shaking machine the extraction of the copper complex increased up to 40 minutes. But here, with carbon tetrachloride, violent shaking by hand for 2 minutes was used to compare sample and standard solution. According to *International Critical Tables* its solubility in water at 20°C. is only 0·08% by weight, whereas that of chloroform is 0·80. For xylene the solubility is immeasurably small; even at 150° (under pressure) it is only 0·088%. This accounts for the slow rate of extraction with xylene as solvent.

Chow and Thompson found a sharp maximum for absorption at 436 mμ with copper and the reagent, which gave with copper a brown precipitate or colour from pH 5 to 10. With ferric and ferrous ions, however, purple precipitates occurred from pH 5 to 7, but no precipitate or colour appeared in the more basic ranges, which include that of sea water. On the other hand, with carbon tetrachloride extraction iron gives a colour like that of copper — brownish, but it is less sensitive. With 5 drops of 2% citric acid with 5 ml. of the 0·1% reagent and 100 ml. of sea water such traces of iron as may be found in sea water cause no error. An attempt was made to estimate copper in sea water directly without extraction, by means of a Unicam spectrophotometer with a 10·0 cm. tube of about 25 ml. capacity. The method was not sensitive enough, but with more copper the effect of citric acid in preventing the interference of iron could be seen. It was also shown that scattering due to suspended matter in the sea water could introduce serious error in the spectrophotometer reading, though after long standing no error could be detected as far down as 400 mμ. The yellow colour of very dilute copper diethyl-dithiocarbamate in sea water gives a rather flat absorption curve

with a minimum at 450 mμ. Comparison between the usual reagent and the diethyl-ammonium-diethyl-dithiocarbamate of Strafford, Wyatt, and Kershaw (1945) showed no difference in colour, or intensity, nor did any such difference appear on standing in daylight for two days. The aqueous solutions are therefore of identical stability. Morita (1955) has given a good list of references and made an extensive survey of the copper and zinc contents of a large series of rocks and waters. Concentration and separation were effected by extraction with dithizone in carbon tetrachloride; the results indicate that the method is delicate. Murakami and Mitani (1955) studied the copper and zinc and natural pigments in green oysters, the flesh of which contains four times as much zinc as it does copper.

Note on Estimation of Zinc

I found (1935, 1936) that sodium diethyl-dithiocarbamate was a far more delicate test for zinc than ferrocyanide, which according to Mullinix and Stallbaumer (1922) was 10 times as delicate as sulphuretted hydrogen. With the sodium compound in neutral solution, and with 200 ml. in a Hehner tube, 8 mg. per m^3. can be detected turbidimetrically; yet it did not detect zinc in the English Channel in late spring. It was shown, however, that lobsters kept in a galvanized iron tank had been poisoned by the zinc in solution, 25 parts per million, which is 3,000–10,000 times as much as is found in sea water. Mayne and Noordhof (1953) improved the turbidimetric estimation by protecting the white precipitate with a 1% solution of purified polyvinyl alcohol. This was used by Evans and Davies (1951) in studying the corrosion of zinc in distilled water.

For its detection in sea water zinc could be deposited by electrolysis, as was copper (1932), and thus brought to a greater concentration, but a new reagent would probably be more convenient. This appears to be unaffected by the other metals of sea water in their usual low concentrations. Krumholz and Krumholz (1935) introduced p-dimethylaminostyryl-β-naphthiazole methiodide and it is now used as a very sensitive test for zinc. Full details of its use have recently been given by Johnson (1955), to whom I am indebted for helpful information previous to the publication of the monograph. According to Osborn (1953) zinc can easily be detected down to about 1 part in a hundred million, namely, 10 mg. per m^3. Thus with a 200 ml. Hehner tube, it could be estimated colorimetrically in the ranges 9–21 mg. per m^3. found spectroscopically by Black and Mitchell (1952) around Gt. Britain and 1·3–11·7 found by Morita near Japan. Of special interest are Morita's findings for Sagami Bay — 2·2 at surface, 2·4 at 200 m., 3·0 at 600 m., and 4·2 at 1000 m. for 12. February 1953, with Cu/Zn ratios for these depths 0·41, 0·33, 0·30, and 0·36.

The purple-black crystalline powder of the methiodide gives a clear deep-red solution in alcohol, with a magenta fluorescence. The red colour is discharged in acidified water and a yellow solution results. With zinc — and other metals in greater amount — the pink colour persists. To 200 ml. of sea water add 50 ml. of 0·1 N sulphuric acid, 2·0 ml. of 7·5 M ammonium thiocyanate, and 4·0 ml. of 0·05% alcoholic solution of the reagent and

compare with a distilled-water blank and appropriate concentrations of a zinc sulphate solution both in distilled and in sea water. The zinc pink is really a coloured suspension which slowly separates. It seems almost impossible to wash this off glassware with water, so acetone should be used. When the colour is too faint for estimation the suspension might be removed by shaking with aluminium oxide, which could then be washed with acetone — or a collodion filter with average pore diameter 0·5–1·0 might retain the suspension along with the trace of clay normally found in sea water. It might even be possible to extract the colour with an immiscible solvent such as carbon tetrachloride. Owing to the very minute amount of iron in sea water the addition of oxalic acid should not be necessary to prevent the iron giving a colour with thiocyanate.

Sommer and Lipman (1927) showed that zinc was necessary for the growth of higher green plants and its four-fold excess over copper in the flesh of the plankton-feeding oyster indicates its importance in the latter.

Note on Estimation of Sugars, "n-ethyl carbazole substances", in Sea Water

The work of Collier, Ray, and Magnitzky (1950) opened up what appears to be one of the most important lines of work in marine biology, and I am much indebted to Dr. Collier for reprints, full written directions, and a supply of n-ethyl carbazole unobtainable in Europe. Unfortunately I could only do preliminary work in the estimation of the sugars, which the Collier group find to be extremely variable and present in from 2 to 25 mg./l. The carbazole test for carbohydrates, developed by Dische (1927), was adapted for the work on sea water by Erdman and Little (1950), who found n-ethyl carbazole better suited. Collier recommends 250 mg. of the latter substance dissolved in 250 ml. of pre-chilled 90% pure sulphuric acid, bottled without the use of a cellulose-compound seal. This gave enough for 48 hours use, stored in a refrigerator. Distilled tap water (chlorinated) sometimes gave a green colour with the reagent. All glassware, including bottles, should be seasoned in sulphuric acid. In direct sunlight the reagent will turn green in a few minutes. It should be mixed and stored in subdued light. The sea water was centrifuged to remove plankton and from the top of the sample 2·5 ml. was removed and mixed in a tube with 22·5 ml. of reagent and hydrolysed for 15 minutes at 70° ± 0·5°C. A small chip of pure paraffin wax was dropped on the surface to exclude oxygen. The sample was then cooled and put in a cuvette for examination after standing long enough to allow bubbles of hydrochloric acid to escape. The filter used in the colorimeter had had maximum transmission at 525 mμ, the green. The concentrations were ascertained by means of a graph obtained with standard dilutions of l-arabinose. These details, and the effect of dissolved organic substances on oysters, are given by Collier, Ray, Magnitzky, and Bell (1953), and are further discussed by Collier (1953).

A surface sample of sea water, from 20 miles off Plymouth, was kept in a brown bottle for 6 weeks, in which time all plankton had settled out. It

gave only a very faint pink colour with the reagent, after heating, but distilled water gave no colour or, looked at down the tube, a blueish tinge. The sea-water pink was about 5 mg./l. arabinose. The sea water of the laboratory circulation gave no pink, but only an intense green, even in the cold. Water from the open sea which had stood in the light so that green algae developed at the bottom gave a good pink, about 20 mg./l. arabinose. A unialgal culture of a red *Cryptomonas*, from Dr. Parke, after standing some weeks gave only green, cold or hot, but a culture of a non-motile green alga gave a good pink, around 50 mg./l. Unfortunately the work had to be abandoned here, but it was obvious that Collier's method was most valuable. Arabinose is a convenient standard sugar, but it is not necessarily what is present in the water or organisms. Following Whistler and Durso (1950) Wangersky (1952) removed carbohydrates from sea water on to a column of activated charcoal. Two crystalline compounds were separated, one of which may be a rhamnoside and the other probably an oxidized ascorbic acid. The former is by far the most abundant carbohydrate in inshore sea water, as much as 0·1 g./l. having been found. Collier *et al.* have shown that the opening and closing of oysters and their pumping activity is controlled by the concentration of substances which give the n-ethyl carbazole reaction.

Summary

A method for estimating ammonia not involving distillation appears to be provided by the use of chloramine T and a pyridine pyrazolone reagent. The advantages of diphenyl benzidine for nitrates are stressed, and reduction to nitrite with a quartz mercury arc is suggested, followed by the Griess-Ilosvay reaction. In the reduction the reaction must be alkaline, over pH 9. For copper with sodium diethyl-dithiocarbamate, extraction with carbon tetrachloride has advantages. In sea-water analysis no gain accrues from using the diethyl-ammonium-diethyl-dithiocarbamate. For zinc the diethyl-dithiocarbamate is preferable to ferrocyanide but p-dimethyl-aminostyryl-β-naphthiazole methiodide is probably better. Sugars, as arabinose, may be estimated in sea water and unialgal cultures by the use of n-ethyl carbazole.

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A Plankton Volume Indicator[1)]

By

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Introduction

It is recognized in marine plankton studies that rather large variations in numbers or volumes of organisms occur with successive catches at the same location, perhaps due to patchiness of organisms, diurnal migration patterns, or sampling errors in the field and laboratory. Because presumably identical field measurements in one location may fluctuate 20 to 40% over a 24-hour period one may be tempted to be unconcerned with such variations in a broad survey programme; however, failure to attempt to eliminate variations of this amount, which may be due to laboratory methods, unnecessarily complicates interpretation of biological cycles in a more exact type of study.

Apparatus for measuring the displacement volume of plankton samples has been designed by a number of investigators who recognized the precision and convenience of measurement possible with a standardized technique (Apstein, 1909; Jacobsen and Paulsen, 1912; Ussachev, 1939; Berardi, 1953; Ealey, 1953). The inclusion of large amounts of water in estimations of volume by the settlement method has been pointed out particularly by Bigelow and Sears (1939), Redfield (1941), and Sheard (1947), who made comparisons with the displacement method. The closer proximity of the latter method to true plankton volumes has been recognized in the utilization of displacement methods by a number of investigators (Leavitt, 1935; Clarke, 1940; Moore, 1949; Gundersen, 1951; Deevey, 1952a, 1952b; Kielhorn, 1952).

[1)] Contribution No. 201 from the Department of Oceanography, University of Washington. This work was supported in part by the Office of Naval Research (Project NR 083 012, N8onr-520/III) and was presented as a technical report on this project, 19. March 1954. A preliminary report was presented at the 24th annual meeting of the Pacific Division of the A. A. A. S., Santa Barbara, California, 17. June 1953.

Disadvantages of conventional method of analysis

A conventional method of plankton volume analysis consists of pouring the catch into a cone-shaped silk net or on a filter disk and allowing excess water to drip from the catch. Additional water is removed by blotting on suitable paper. The catch is then added to a known volume of water and the additional volume registered is a measure of the displacement volume of the zooplankton.

The disadvantages of the technique are as follows: — (1) the process of draining the water from the sample is slow; (2) some of the animals remain attached to the net or disk when the catch is removed, or are damaged when scraped from the filter or net; (3) with extended blotting time, animals around the periphery of the mass become drier than the remainder and will float when they are added to the graduated cylinder of water, making volumes difficult to estimate; (4) the method fails to remove large amounts of interstitial water between the organisms.

The problems presented in use of the earlier instruments with the usual inclusion of large amounts of interstitial water in the measurements and the differences in technique of conventional displacement volume measurement led to the construction of the apparatus now described. This apparatus not only permits more accurate and rapid measurement of the true plankton volumes, but also leaves the organisms in good condition for later, more detailed qualitative and quantitative studies. The instrument was built specifically to measure volumes of organisms of the type obtained with the Clarke-Bumpus plankton sampler (Clarke and Bumpus, 1940) in the neritic zone.

Description of the instrument

The instrument consists of two principal parts, A and B, constructed of Pyrex glass (Fig. 1A). A is a cylindrical section (1) connected to the upper half (2a) of a calibrated chamber by a constricted tube (3). B consists of the lower half of the calibrated chamber (2b) at the base of which is a fritted glass disk (4) with a pore diameter of 40 μ. A stopcock (5) controls the flow of liquid. Division of the calibrated chamber permits the removal of the sample from the filter. The chamber halves when joined have an airtight, lightly greased seal. The volume of the chamber from the graduation mark (x) to the disk is approximately 48 ml., but the exact volume must be ascertained by calibration.

Manipulation

With the apparatus assembled for operation (Fig. 1B), the plankton and water are stirred and the mixture transferred to the chamber with a large-mouth syringe pipette, filling to the graduation mark. Care is taken to eject the sample as a gentle stream through the narrow constriction to prevent clogging, or forcing the water through the filter disk. The difference between chamber volume and the interstitial water filtered into the graduated cylinder is a measure of the plankton volume. Standardization of filtration

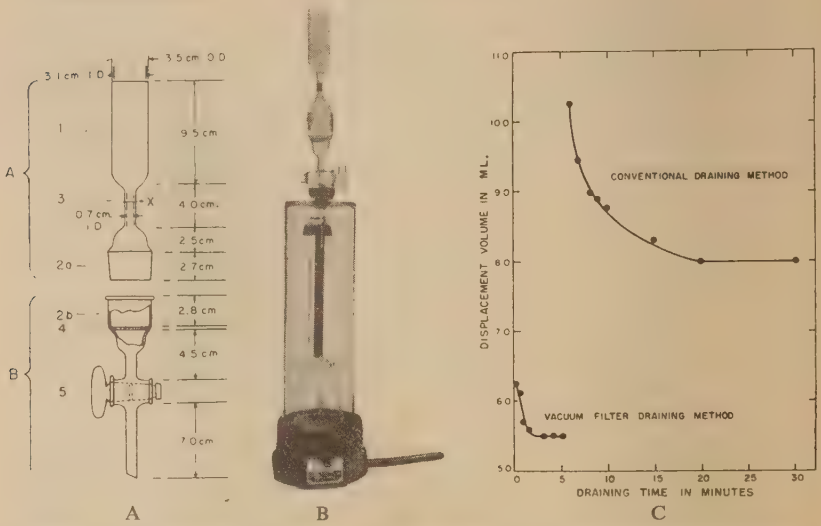

Figure 1. (A) Diagram of plankton volume indicator. (B) Plankton volume indicator assembled for operation. (C) Comparison of a typical plankton sample volume collected with a No. 6 net at Station B (see Table 1) as determined by conventional draining method and by plankton indicator.

time is essential. It was found that 5 minutes of aspiration was sufficient to cover most samples. Upon completion of the volume measurement the plankton on the filter was removed by a jet of water without apparent damage to the organisms. This volume containing the resuspended material is then transferred quantitatively to the volume chamber and the measurement repeated. The second reading usually checks the first within 0·2 ml.

Check readings cannot be obtained, however, simply by placing water in the chamber over the plankton retained on the disk, as air bubbles resulting from previous drainage will cause differences considerably greater than 0·2 ml. in presumed plankton volumes.

The filter disk should occasionally be treated with chromic acid to ensure proper drainage, as with continual use the disk becomes more or less clogged.

Samples analysed

Samples used in testing the instrument were collected with a Clarke-Bumpus sampler at approximately weekly intervals during an 18-month period 1950 51, at two stations in Narragansett Bay, R. I. In all, 235 samples were analysed in duplicate. A comparison of differences in duplicate analyses of these samples is summarized in Table 1.

The bulk of the interstitial water in most of the samples drained through the apparatus in 10 to 15 seconds with the last of the removable water usually drained in 3 minutes. Samples with much fine material such as phytoplankton, detritus, etc. required as long as 5 minutes for draining.

Table 1

Comparison of volumetric difference in duplicate analyses based on total catch measured in plankton volume displacement indicator[1])

Clarke-Bumpus net No.	Station[2])	Number of hauls[3])	Measurements of volume frequency	Comparative sample volumes (in millilitres) Difference classes between duplicates	Avg. vol. of all	Max. vol. of single sample	Min. vol. of single sample	95 % confidence interval on mean of dupl. analyses
6	A	53	35	0·0	1·8	9·1	0·3	$\bar{x} \pm 0{\cdot}07$ ml.
			14	0·1	3·4	8·5	0·2	
			4	0·2	1·6	3·0	0·5	
	B	77	45	0·0	3·4	8·1	0·2	$\bar{x} \pm 0{\cdot}10$ ml.
			21	0·1	3·1	6·3	0·2	
			10	0·2	3·7	5·9	1·5	
			1	0·3	–	–	–	
14	A	50	31	0·0	1·4	5·1	0·1	$\bar{x} \pm 0{\cdot}07$ ml.
			18	0·1	1·0	5·6	0·1	
			1	0·2	–	–	–	
	B	55	32	0·0	0·8	3·2	0·1	$\bar{x} \pm 0{\cdot}07$ ml.
			22	0·1	0·8	2·2	0·1	
			1	0·2	–	–	–	

[1]) All samples taken usually at weekly intervals between 25. July 1950 and 27. December 1951.

[2]) Station A — Lat. 41°19·8′ N., Long. 71°31·4′ W.
Station B — Lat. 41°29·7′ N., Long. 71°24·9′ W.

[3]) Oblique, of 20-minute duration from near bottom to surface.

Comparison with previous method of volume measurement

To compare differences in results obtained by the plankton volume indicator and the usual displacement volume technique, 20 of the samples listed in Table 1 were selected for means of comparison of the two methods. The samples selected showed decided variation with respect to species, time of year, plankton volume, station location, and mesh of net. Of these samples, 10 were from the offshore station and 10 from the bay station. Half of these were collected with a No. 6 net with a mesh opening of 0·239 mm. and half with a No. 14 net with a mesh opening of 0·099 mm. (Sverdrup, Johnson, and Fleming, 1946, p. 378).

For the No. 6 net samples drained with the plankton indicator, the average of 10 plankton volumes measured was 19·4 % less than the average volume of the same samples measured by the conventional displacement procedure, while that for the 10 No. 14 net samples was 27·5 % less.

Both fine and coarse net samples retain water in the interstices between the organisms that is not removed by gravity draining; hence the desirability of vacuum filtration (Fig. 1C). The fine-mesh catches apparently hold a greater volume of water per unit volume of catch than do the coarse-net samples. The water retained is a function of the size of the organisms; thus catches with the smaller-mesh net will retain more water than catches of the large-mesh net per unit volume of plankton sample, due to capillarity and area of surface.

Redfield (1941, p. 87), in deriving his factor of 4·9 for converting settlement volume to displacement volume, collected the plankton on a

filter paper in a Buchner funnel and introduced this "dry" plankton into a measured volume of fluid to estimate its displacement volume. Thus the use of this value of 4·9 for conversion of volumes probably gives results which would be quite similar to those obtained by direct displacement volume measurement with the plankton volume indicator. However, in summarizing data for comparative purposes one cannot directly compare such results with displacement volumes measured by conventional draining and blotting because of the relatively large amounts of water left in the interstices between the organisms by the latter method.

RILEY, STOMMEL, and BUMPUS (1949, p. 35) made comparative measurements of 20 plankton samples using a "displacement weight" and a "wet weight" in which the animals were prepared by rolling on filter paper. Their results of weight losses of 20 to 30% with extreme differences of 45% are in close accord with those obtained in this study.

In order to estimate the volume error of duplicate measurements a statistical analysis was made of the four separate groups of samples, namely, the No. 6 and No. 14 net catches from Station A, and the No. 6 and No. 14 net catches from Station B. To eliminate the possibility of gross error, all samples were run in duplicate. The precision of the measured volume of the sample can be determined after the error inherent in the operation of the instrument is known.

As shown in Table 1, the volumes of duplicate analyses of most samples differ by less than 0·1 ml., although variation as great as 0·3 ml. may sometimes occur. To ascertain the precision of any sample analysed in duplicate, the volumes of the 235 samples were statistically treated. For the four groups of samples analysed, the 95% confidence interval for the mean of duplicate analyses was in no case more than $\pm$0·1 ml. and in three out of four groups was $\pm$0·07 ml.

Summary

A plankton volume indicator is described, the advantages of which over the conventional method of displacement volume measurements may be listed as follows: — (1) it is more rapid; (2) approximately 19 to 27% more water is removed than by the conventional draining method; (3) the apparatus ensures a standardized treatment of all samples; (4) the organisms are handled in a water medium, which minimizes damage and thus permits further studies for positive identification and accurate counts of the organisms; (5) the volume measurements are reproducible; (6) the instrument is easily constructed of standard laboratory glassware.

The shortcomings of the instrument are: — (1) possible variations in porosity of filter disks; (2) large or gelatinous forms may offer difficulty in measurement.

Acknowledgement

The author wishes to thank Drs. H. R. GOULD, T. G. THOMPSON, and D. G. CHAPMAN, and Mr. C. O. JUNGE for their helpful criticisms and suggestions.

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Improvements in the Clarke-Bumpus Plankton Sampler[1)]

By

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The plankton sampler described by CLARKE and BUMPUS (1940, 1950) has seen considerable application, particularly because of its convenient size, and the fact that it may be made to open and close again at chosen depths while the water passing is metered and, furthermore, may be operated with several samplers in sequence on the line. But in our experience the unreliability of the opening and closing mechanism, the difficulty of cocking in unskilled hands, and the ease with which it can get out of adjustment have discouraged the use of this feature of the instrument.

The tripping device was recently modified to be easier to cock and more reliable in operation. The basic construction of the opening and closing mechanism has not been changed, but the trigger arm on which the messengers act has been redesigned. Originally, the triggering mechanism depended for its action on a specially shaped first messenger moving the trigger arm at a rather poor mechanical advantage, and then sliding by while dissipating most of its energy against friction. Often the energy was all absorbed before the messenger had passed.

In the improved form, friction has been greatly reduced. The trigger arm has been lengthened to form a fork which straddles the line, and the restraining spring has been strengthened so that it will hold more than the static weight of two messengers on the fork, yet yield momentarily to the kinetic energy of either falling messenger sufficiently to operate the tripping mechanism. The messengers do not slide by the fork but rest upon it, and

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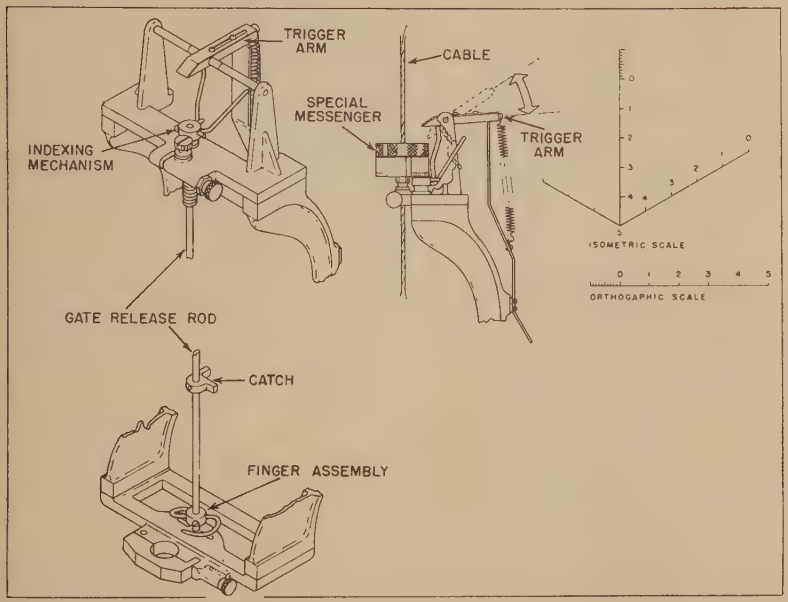

Figure 1. Clarke-Bumpus Plankton Sampler — details of original construction.

each impact produces a single down-and-up motion of the fork. A stop has been added to limit the motion of the fork. A similar principle has been used in the Ekman current-meter (EKMAN, 1932). These changes may be seen by reference to Figures 1 and 2, which show the original and improved versions respectively. Figure 3 shows the complete sampler as modified.

The spring must be adjusted for a particular type and weight of messenger. A small messenger of 310 grammes[1]) works well with a spring consisting of 30 active turns of 0·041-inch spring K-Monel close-wound on a $\frac{1}{4}$-inch mandrel and extended to 2·88 inches active length. As a workable laboratory test, the spring is properly adjusted if it will support three messengers on the fork without deflection, but permit satisfactory operation of the trigger when a single messenger falls vertically on the fork from a height of 9 inches or less in air.

These criteria have been found satisfactory for our field operations at speeds up to 4 knots, wire angle at the instrument approximately 45°, and wire tension of about 300 pounds produced by a depressor. No difficulty arises at lower speeds with the same depressor or 100 pounds of weight. If the sampler is to be used at very large wire-angles with small weights, heavier messengers or a weaker spring may be required.

[1]) e. g., Cat. No. 333 of Kahl Scientific Instrument Corp., P. O. Box 1166, El Cajon, California.

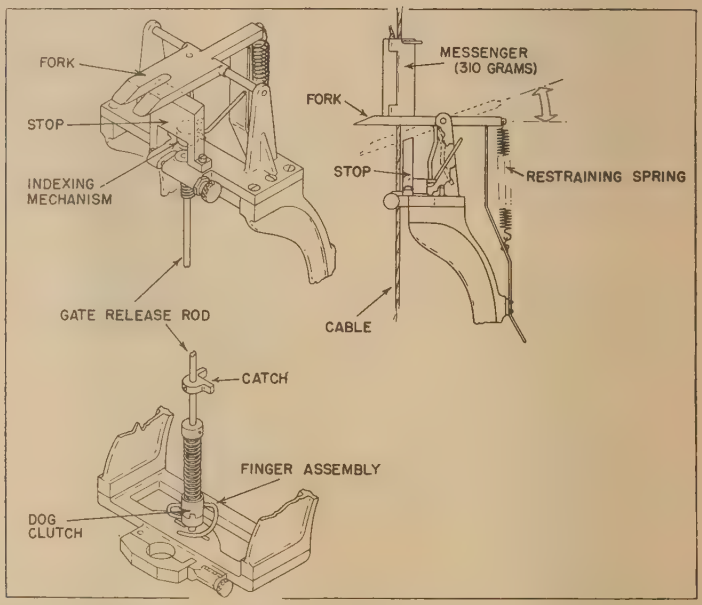

Figure 2. Clarke-Bumpus Plankton Sampler — details of modified construction.

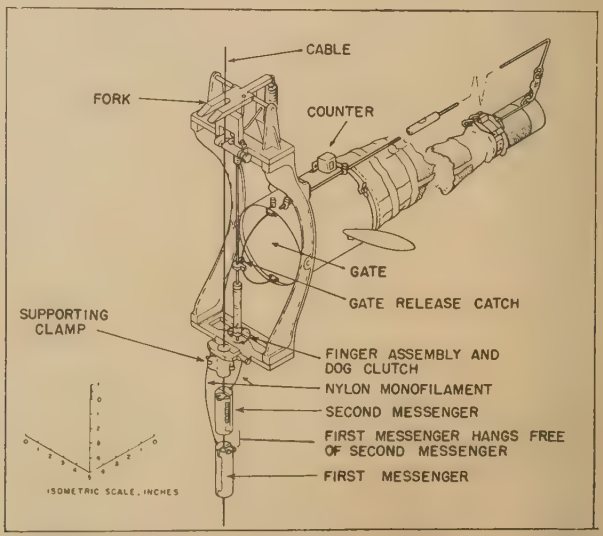

Figure 3. Clarke-Bumpus Plankton Sampler — complete sampler as modified.

The second improvement has to do with the device which drops the two messengers in succession from the sampler when a second sampler below is to be actuated. On the original sampler, attaching these messengers and cocking the gate mechanism is quite an awkward operation since three separate parts must be manipulated simultaneously. In the improved version the finger assembly which holds the messengers is no longer fixed to the rod which actuates the gate release, but it can be rotated by disengaging a retractable dog-clutch. This permits the gate to be cocked and the messengers attached afterwards. In Figure 2 the lower half of the clutch is fixed to the rod with a set-screw whereas the upper portion, which carries the fingers, is free to rotate when it is retracted. The spring fits into a socket in the upper half of the clutch and serves to keep the two parts in engagement; it is free to rotate and is merely restrained longitudinally by the upper collar.

These two changes have proved very satisfactory in the field. Five Clarke-Bumpus samplers have been converted in this way in our laboratories, and jointly they have been operated over 400 times with no failures attributable to the mechanism.

It is regrettable that some commercially available samplers show the effects of inattention to the details of good construction and design. Some of the flaws which have been found are: — (1) included angle of conical pivots equal to those of their sockets; the pivot should always be more acute: (2) fork-to-pin linkage between worm-gear shaft and counter too close a fit and hence very sensitive to misalignment: (3) L-shaped catch not tight on rod; it should be pinned and soft-soldered in place: (4) clamp which fastens the sampler to the line either too large or too close a fit, so that the sampler will not rotate around the clamp and the clamps are generally not interchangeable among samplers: and (5) central pin on the indexing mechanism not bent upward far enough near the collar; this pin should limit the rotation of the rod to a single step with ample margin of safety, so that a little bounce of the first messenger on the fork cannot cause both steps to occur.

An item of technique which will improve convenience and accuracy is the following. The counters, even though filled with oil, are prone to leak and become corroded by salt water. In our experience, the greatest single cause of this is the difficulty of filling the counter completely full of oil by ordinary techniques. If the counter is immersed with the shaft upwards in a container of oil and subjected to several surges of reduced pressure, it readily fills completely and then is much less subject to leakage. This may be done in a vacuum desiccator or other simpler container, and with only moderate vacuum.

W. H. Harvey has constructed a modification of the Clarke-Bumpus sampler which is not yet described in publication. In this modification the turns of the propeller are indicated by a mechanism freely flooded by the water and based on simple gearing which has less friction than the decimal counter used in the present instrument. As a result, corrosion of parts is less troublesome and the linear portion of the calibration curve extends to lower water velocities.

The calibration curve of the present instrument deviates 5% from linearity at a lower limit of 16 to 25 centimetres per second. Increased sensitivity

might be useful if the sampler is to be used from a very slowly moving boat, but in most work done from power vessels such low apparent velocities are reached only when the net becomes badly clogged. When this occurs the distribution of water velocity across the propeller is altered or even partially reversed, and the metered flows are in serious error or meaningless. If it were necessary to work under such conditions, the behaviour of the meter could be improved by providing the propeller with a large streamlined hub.

The meters have been calibrated by towing the sampler without a net, and by direct volumetric measurement in a flume in which the entire flow is directed into the sampler by mounting the latter in an opening in a dam. In the former method, correction is made for the fact that the sampler accepts only about 85 to 90% of the volume of water swept.

Some of the details of calibration and the dynamic behaviour of the meter in the various velocity ranges, with and without nets, will be the subject of an article by C. S. YENTSCH and A. C. DUXBURY of this Department.

Summary

The Clarke-Bumpus plankton sampler is a small, metered, net-towing device which may be opened and closed by messenger when several samplers are in sequence on a line. Simple changes are described which make the instrument easier to cock and thoroughly reliable in operation. Some of the common flaws in construction are indicated. It is noted that the metering device fails when the net becomes badly clogged.

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Flotation Technique for Sorting Grab Samples

By

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TYPICAL grab samples from the Dogger Bank may consist, after sieving, of 1 or 2 litres of dead shell, in amongst which there may be between 200 and 1,000 animals. The laboratory sorting of the collection from a whole cruise, perhaps 150 samples, of which a half will be of this character, has in the past presented a serious problem. Several techniques have been tried with the object of finding a purely mechanical process, which will take only a short time for each sample and which, if possible, can be relied on for use at sea. The carbon tetrachloride flotation technique seems to have fulfilled this hope, and is to be described here, together with the only other mechanical technique which approached it in efficiency, the two having been subjected to detailed efficiency tests. Various flotation methods were tried -- medicinal paraffin, for instance, which proved too messy although it promised well; and a stream of air bubbles passing through the sample in a beaker, which was effective only with light, hairy organisms such as amphipods and polychaetes. The sorting drum (Figure 1) was an advance on the second of these techniques in that the sample was continually disturbed by the rotation of the drum at a slow speed, the current of water carrying organisms away through the spout to be filtered off through silk. It was useless for sorting molluscs and echinoderms, and the weight of the drum and its contents on the friction rollers made it ineffective in a pitching ship. We therefore resorted again to flotation techniques. The ideal flotation fluid should separate all the living organisms from the masses of dead shell or gravel, in which they are contained. Thus it should be intermediate in density between that of dead shell and a shell containing the organism; it should not damage the organisms — either by chemical action on the shell, or by osmotic action on the flesh; and it should work rapidly and be free from mess.

After a search through tables of physical constants, it was decided to try carbon tetrachloride (CCl_4), and it instantly proved to be highly successful, since it possessed all the features of the ideal flotation fluid mentioned above.

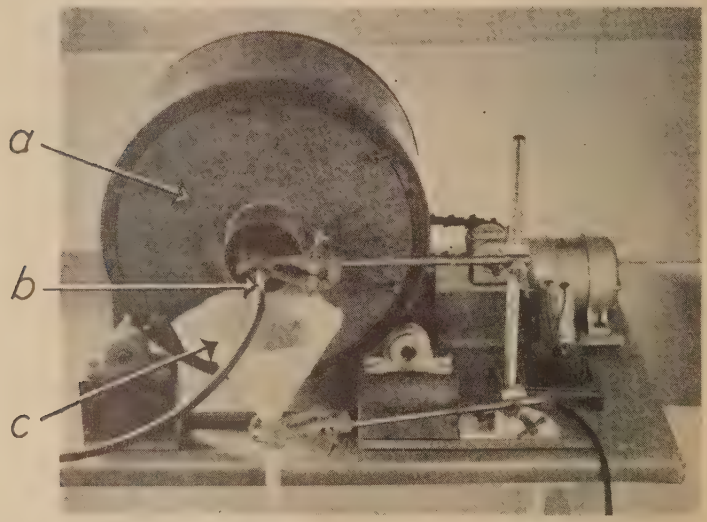

Figure 1. The machine-sorting technique.
a = the drum which contains the sample, and rotates slowly
b = water jet playing on the sample c = fine-silk strainer

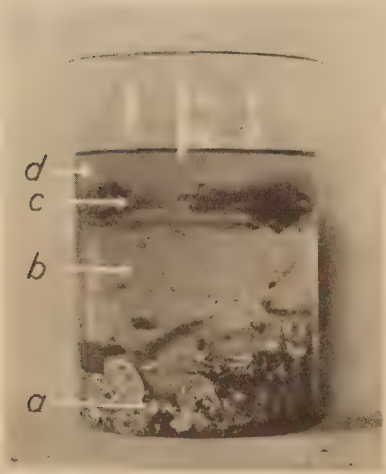

Figure 2. The flotation technique.
a = dead shell and other matter
b = carbon tetrachloride
c = animals floating at the interface
d = water

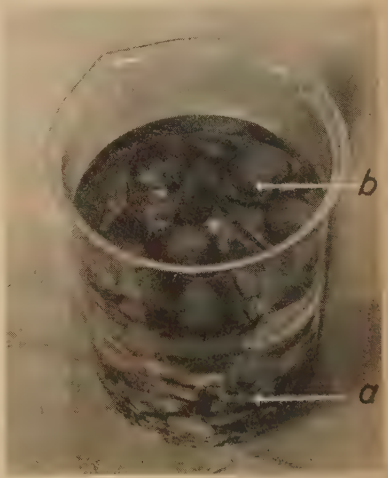

Figure 3. The flotation technique.
a = dead shell and other matter
b = animals floating at the interface

The method of application is: — place the sample in about ½ litre of sea water (or formalin) in a plastic bucket or a glass beaker, add 1–2 litres CCl_4, stir with a glass or wooden rod for a few moments only, and then decant off the epiphase (aqueous) and the top of the CCl_4. The organisms all float at the interface, nearly free from shell, etc. (Figures 2 and 3), and may be filtered off and bottled for identification, counting, and measuring. The dead shell is then hand-sorted for the small proportion of organisms remaining in it, which may have been trapped underneath shells. The only species which have been found too dense for flotation are large *Cyprina islandica*, *Donax vittatus*, and some echinoids; large *Asterias rubens* float off just as easily as *Mactra* or small amphipods. The CCl_4 is easily reclaimed through a separating funnel.

A comparison was made of three methods of sorting used in this laboratory: —

(1) hand-sorting to pick out all obvious organisms, followed by agitation and decantation for small animals which had been missed;
(2) machine-sorting, followed by hand-sorting; and
(3) CCl_4 flotation, followed by hand-sorting.

Eighteen samples were used, which represented triplicate hauls with the $^1/_5$ m². van Veen grab at 6 positions on the Dogger Bank ("Sir Lancelot", Cruise 16, October 1954). One sample from each station was dealt with by each of the three methods, and the following tables summarize the results; the total time taken with each process is also given.

Table 1

Total number (T) of each group recorded per sample, and the proportion (%) which each technique sorted out

Station	91		11		72		22		39		50	
	T	%	T	%	T	%	T	%	T	%	T	%
Molluscs												
Hand-sorted	1	*100*	14	*100*	29	*100*	21	*100*	55	*100*	579	*100*
Machine-sorted....	2	*0*	10	*20*	28	*71*	30	*20*	29	*0*	643	*7*
CCl_4-sorted	1	*100*	6	*83*	19	*100*	38	*63*	29	*72*	523	*90*
Polychaetes												
Hand-sorted	21	*100*	60	*82*	88	*88*	220	*97*	349	*86*	108	*94*
Machine-sorted....	22	*77*	156	*65*	80	*84*	188	*75*	306	*45*	128	*48*
CCl_4-sorted	24	*83*	23	*61*	67	*87*	194	*63*	183	*87*	76	*78*
Crustaceans												
Hand-sorted	19	*100*	43	*72*	13	*77*	13	*92*	91	*47*	65	*77*
Machine-sorted....	2	*100*	52	*92*	19	*74*	22	*86*	73	*93*	55	*56*
CCl_4-sorted	23	*57*	10	*50*	11	*100*	33	*79*	70	*79*	33	*94*
Echinoderms												
Hand-sorted	1	*100*	5	*100*	28	*14*	5	*60*	2	*100*	18	*100*
Machine-sorted....	–	–	2	*100*	89	*58*	14	*50*	–	–	25	*12*
CCl_4-sorted.....	2	*100*	–	–	31	*81*	6	*83*	1	*100*	3	*33*
Other Groups												
Hand-sorted	1	*100*	5	*60*	10	*80*	3	*67*	21	*52*	22	*95*
Machine-sorted....	–	–	14	*29*	14	*93*	2	*50*	12	*50*	25	*28*
CCl_4-sorted.....	–	–	5	*80*	17	*88*	6	*83*	17	*100*	18	*78*
Total Animals												
Hand-sorted	43	*100*	127	*80*	168	*76*	262	*96*	518	*80*	792	*97*
Machine-sorted....	26	*73*	234	*67*	230	*72*	256	*68*	420	*50*	876	*17*
CCl_4-sorted.....	50	*72*	44	*64*	145	*88*	277	*66*	300	*84*	653	*88*

Table 2

Volume (in ml.) of dead shell in the samples used in the tests of methods

Animals Station	91	11	72	22	39	50
Hand-sorted	60	500	65	n.r.	900	n.r.
Machine-sorted....	100	840	60	130	460	80
CCl_4-sorted.....	140	450	60	200	440	40

(n.r. = not recorded)

Table 3

Total time taken (in hours) for sorting the samples used in the tests of methods

Animals Station	91	11	72	22	39	50	Total for six samples
Hand-sorted	$\frac{1}{3}$	3	$2\frac{1}{2}$	$4\frac{1}{2}$	5	3	$18\frac{1}{3}$
Machine-sorted.....	$\frac{1}{2}$	1	$1\frac{1}{2}$	$1\frac{1}{2}$	$1\frac{1}{2}$	3	9
CCl_4-sorted.....	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{1}{3}$	$1\frac{1}{2}$	$1\frac{1}{2}$	$\frac{1}{2}$	$4\frac{1}{2}$

Table 3 shows the great reduction in the time needed to sort a sample when the CCl_4 technique is used. The average time taken, about 45 minutes, enables the sorting to be done between successive stations on a grabbing cruise.

Of course hand-sorting is highly efficient, but it absorbs a great deal of time. Machine-sorting fails to separate out the heavy organisms. The CCl_4 technique overcomes both these faults, and it should be noted that the times recorded in Table 3 include the flotation and the small amount of hand-sorting which was carried out, but which could have been avoided by repeated flotation.

My thanks are due to my assistant, Mr. B. C. HOWARD, who was largely responsible for the development of the technique.

Summary

A technique is described for rapid sorting of grab samples. The living organisms are floated off from the dead shells or gravel on carbon tetrachloride. This medium has many advantages over inorganic solutions, and greatly reduces the time taken to sort samples by hand or by machine.

A Sampler for Underwater Macrovegetation in Shallow Waters

By

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Danish Institute for Fisheries and Marine Research

The Danish Heath Society has in recent years advanced certain projects for draining a number of shallow indentations — inlets, bays, and coves — on the Danish coasts with a view to using the reclaimed areas for farming. These projects have led the Danish Institute for Fisheries and Marine Research to carry out extensive biological investigations in a number of localities of this kind, one object being to evaluate the primary production. These investigations on productivity have hitherto been limited to the phytoplankton (Grøntved, 1956; Grøntved and Steemann Nielsen, 1957) and the microscopic bottom vegetation (Grøntved, in preparation). It seemed desirable, however, that provisions should be made for comparison of the quantities of the macrovegetation produced in these areas. The first problem that arises in this connexion is the construction of an apparatus for quantitative sampling of the flowering plants and higher algae.

The well known Petersen bottom sampler (C. G. Johs. Petersen, 1911; see pp. 46–47, Pl. 1, Figures 1–3) was originally constructed for the collection of animal material. Petersen, however, also used the gear for sampling crops of eel-grass and appears on the whole to have been satisfied with the results, though he admits that "a very sharp cutting instrument which did not push away the leaves when lowered to the bottom and which cut off leaves and roots within the area covered might be considered to give more reliable results". A sampler constructed in accordance with these suggestions is described below.

The apparatus consists of two main parts — a cylinder (A) and a shaft (B), the first of which cuts off the sample vertically, the second horizontally.

The lower part of the cylinder (a), height 36 cm., diameter 25 cm., is made of perforated iron plate; it is fitted at the lower end with a fairly thick ring

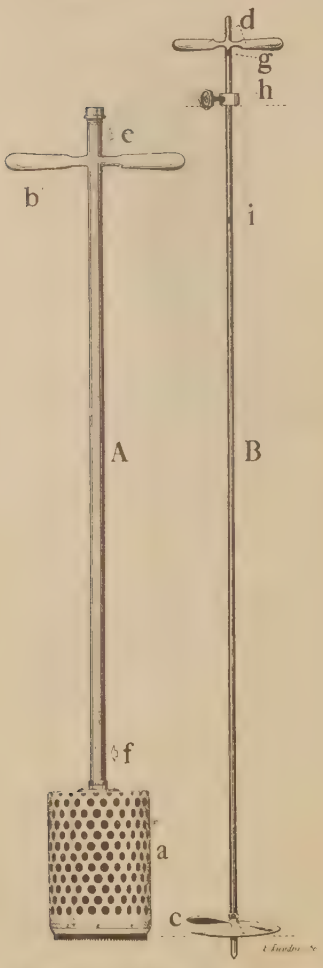

Figure 1. The construction of the sampler, the two principal parts, the cylinder, A, and the shaft, B, being shown separately.

with an inner groove in which a saw-blade is attached by screws in such a way that it may be easily replaced; the saw-blade forms a ring with an inside diameter of 22·6 cm. An iron plate (unperforated) is welded to the upper end of this part of the cylinder. Into the centre of this top plate an iron tube is fitted (length 166 cm., outside diameter 34 cm., opening 29 mm.), the upper end of which carries two handles (b) at right angles to the tube; they are employed to rotate the cylinder on its axis so that the saw cuts through the plants, and limits the sample vertically. The external part of the instrument is made of iron and with the exception of the saw-blade, is galvanized throughout.

The internal part (B) is made of stainless-steel rod (length 230 cm., diameter 16 mm.), to the lower end of which a plate is attached (thickness 2 mm., diameter 21 cm.). A curved incision is made in this plate from the rim towards the centre and the plate is then bent to form a screw-thread with a pitch of 35 mm. The lower lobe of the plate is sharpened to form a curved cutting edge (c) which severs the plant stems, etc. when the shaft is rotated by the handles (d). The shaft (B) is held in place in the cylinder (A) by two ebonite bearings (at e and f) and by a locking ring which may be set at different heights on the shaft.

Before the sampler is operated, the shaft is set at its highest position (with the locking ring at i). The sampler is then lowered slowly, to avoid disturbing the water and causing some of the plants in the area to be sampled to be missed by the cylinder. Long leaves of eel-grass or whole *Chara* plants, which stand more or less vertical in the water, will be caught by the cylinder when it is lowered slowly.

When the sampler reaches the bottom, the lower pair of handles (b) are turned to and fro through short arcs; this causes the saw to cut through the plants a little way below the level of the bottom. The shaft is now lowered, so that the plate rests on the material in the cylinder. The locking ring is set at (h), and the shaft is rotated by the handles (d) so that a spiral cut is made

horizontally through the plants (and bottom material) which have already been severed vertically. When the plate has reached the same depth as the points of the saw teeth — the locking ring is set so that the plate can go no deeper — it forms the bottom of the cylinder, and keeps the sample from falling out.

The sampler is then lifted and the locking ring set at position (g), so that the bottom plate can be pushed clear of the cylinder and the sample emptied out. The bottom material is washed from the plants, which are then stored in sample bottles for subsequent examination.

One may of course vary the distance into the bottom at which the sample is cut off, and make sure that all the subterranean parts of the plants are collected. Some damage to the plants is unavoidable, but it does not preclude the use of the samples for qualitative examination; for our purpose, the determination of the amount of dry plant matter and protein in the various areas, the sampler described has functioned quite satisfactorily.

The saw-blade employed should be set cross-cut; that is, the setting should be that ordinarily used to cut across the length direction of the wood fibres. It is obvious that the cutting parts of the apparatus — the saw and the horizontal knife — should be kept sharp. If several samples are to be taken in localities where stones and gravel occur, it is necessary to provide oneself with a file to sharpen the saw and the knife, or else to carry extra blades as replacements.

The sampler described above is designed for use in depths of not more than 2 metres. It weighs about 17 kg., and may be operated from a motor-boat or a dinghy. With some modification of the dimensions the same design may be employed for somewhat deeper waters. The area sampled, which is about 1/25 m^2. in our case, may be reduced, if circumstances make it desirable, but it is hardly advisable to enlarge it much beyond 1/20 m^2., as the apparatus then becomes rather awkward to handle.

The apparatus was employed for collecting samples on Næraa Strand — a sheltered bay on the north coast of Funen — on 31. October 1956 and again in Dybsø Fjord on the south-west coast of Sealand on 8. November 1956.

The water area of Næraa Strand amounts to about 430 hectares; in the southern part of the bay the bottom is sandy mud and the water is deepest there (a little more than 1 m.); the remainder is quite shallow and the bottom consists chiefly of sand. Twenty-eight samples, regularly spaced over the area, were taken of the macrovegetation, the predominant species in the deeper part being *Zostera marina; Ruppia* predominated in shallower water, and *Fucus vesiculosus* occurred here and there near the mouth of the inlet. Several smaller algae occurred in the samples; with the exception of *Chaetomorpha linum*, they were not of any quantitative importance. No plant material was found in 2 samples; in the remaining 26 samples the dry matter varied from 23 g./m^2. to 379 g./m^2., the average content of dry matter in all 28 samples being 160 g./m^2. The average nitrogen and protein contents of the dry matter were 1·60% and 10% respectively[1]).

[1]) Small particles of the bottom material which cannot be rinsed off the roots and rhizoids tend to give rather high dry-matter values, and so do the calcareous encrustations on *Chara*. Consequently the percentage of nitrogen in the dry matter is fairly low.

The water area of Dybsø Fjord is about 1700 hectares, the greatest depth being about 2 metres. The macrovegetation, which consisted almost entirely of the Characeae, was especially dense in the inner part of the bay where there is most mud. *Zostera marina*, *Potamogeton pectinatus*, and *Fucus vesiculosus* occurred in considerable quantities only over small areas in the outer part of the bay. Twenty-six samples of vegetation were taken at regular intervals from all parts of the fjord.

The average content of dry matter in these 26 samples was 328 g./m^2., the contents varying between 37 g./m^2. and 854 g./m^2. The average nitrogen and protein contents of the dry matter were 1·62 % and 10·13 % respectively.

Using samples obtained with the Petersen bottom sampler, C. G. Johs. PETERSEN estimated (1913) — by doubling the values found for the standing crop in late summer — the yearly production of *Zostera* at 1920, 1120, and 544 g. of dry matter per m^2. in favourable, medium, and poor localities, respectively, in Danish waters. He admits that even poorer localities exist, but in his evaluation of yearly production he keeps to the figures quoted above.

In 12 of the samples containing vegetation from Næraa Strand *Zostera marina* was predominant. These 12 samples contained on an average 211 g. dry matter per m^2., which is considerably above the average for all the samples, but the productivity value (211 × 2) comparable with PETERSEN's figures is nevertheless below that found by him for poor localities. This is indeed as is to be expected. Næraa Strand is too shallow and the bottom is in most places too sandy to permit maximal production of eel-grass. It is moreover a material point that our samples were taken later in the year than those taken by PETERSEN. By the end of October a considerable part of the vegetation produced in the preceding summer had been washed up on the beach or was lying in small heaps in the shallow water just off the beach (cf. Figure 5). It may also be mentioned that in many places near our coasts the crop of eel-grass is not as vigorous as it was before the epidemic eel-grass disease broke out in the early 'thirties.

As regards the samples from Dybsø Fjord, *Zostera marina* was found to be the predominant species in only one case. In 22 out of 26 samples Characeae were the most numerous species. Consequently the relatively high content of dry matter must be attributed to these species. Conditions in Dybsø Fjord resembled those in Næraa Strand in that a considerable proportion of the plants produced that summer had been loosened from the bottom or although still rooted were withering when the samples were collected.

With regard to the Characeae, the biology of which is incompletely known, it is not possible to estimate the yearly production on the basis of the standing crop at the end of the autumn. The estimation of yearly production of macrovegetation in Dybsø Fjord requires the collection of samples two or more times during the year.

The *Ruppia* vegetation in Næraa Strand should be assessed in spring and autumn and I am of the opinion that two yearly assessments of the quantity of *Zostera* present would allow of a more correct estimate of the yearly production in our waters than the single determination of the dry matter in late summer made by C. G. JOHS. PETERSEN.

Figure 2. Næraa Strand, 31. 10. 1956, depth 40 cm. The sampler has been lowered and the horizontal knife is rotated by the handles on the shaft.

Figure 3. Næraa Strand, 31. 10. 1956, depth 40 cm. The sampler containing the sample is raised.

Figure 4. Næraa Strand, 31. 10. 1956, depth 40 cm. The shaft is set at its lowest position and the sample is emptied out.

Figure 5. Næraa Strand 31. 10. 1956. The eastern side of the inner part of the bay is the shallowest. In the foreground there are masses of *Zostera marina* and *Chaetomorpha linum*, which have been loosened and washed up. The water level at this time was very low, and the bottom was temporarily exposed. In the background a wind-mill can be seen pumping water into the bay from the low-lying farm land nearby.

The studies now started of the macrovegetation in shallow coastal waters are, as mentioned above, part of a large biological investigation. With regard to primary production, it seems that the most important factor is usually the benthic microvegetation, and that the quantity of matter produced under optimal conditions by microbenthos surpasses that which our investigations so far give reason to expect from underwater flowering plants and higher algae in these localities. In this connexion it may be mentioned that a comparison between the production of the microvegetation in Næraa Strand and in Dybsø Fjord gives by far the greater value for Næraa Strand, while — as we have just seen — the macroscopic plant growths preponderate in Dybsø Fjord. A certain competition exists of course between macro- and microvegetation on the bottom, the microvegetation having relatively little opportunity for development in places carrying dense growths of the larger plants.

Although the macrovegetation cannot be considered of any great importance as far as productivity is concerned, it should not be overlooked when comparing localities. By reducing water movement, by keeping together loose bottom material, and by serving as a habitat or substratum for animals and plants, the macrovegetation is of no small consequence biologically. An analysis of the crops such as the present one can provide information on this matter.

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Perennial Changes of *Laminaria cloustoni* Edm. on the Coasts of Scotland

By

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As part of the research programme of the Institute of Seaweed Research, an extensive sublittoral survey of the Laminariaceae growing around Scotland has been in continuous operation from 1946 to 1956.

The whole of the marine coast of Scotland — over 6,000 miles — was photographed from the air by the Royal Air Force. From the serial photographs, coupled with ecological factors revealed by the data obtained from detailed surveys, a preliminary survey and a quantitative assessment of the Laminariaceae around Scotland was made (Walker, 1954). Detailed surveying was carried out from motor vessels at all times of the year, the methods used being quadrat sampling with spring grabs (Walker, 1947).

A study of the seasonal variations of a crop dominated by *Laminaria cloustoni* Edm. (*L. hyperborea* (Gunn.) Fosl.), a member of the Phaeophyceae, was made in 1952 (Walker and Richardson, 1955) in three widely separated habitats, namely, Girvan to Bennane Head, Dunbar to Fast Castle, and Fraserburgh to Rosehearty (Figure 1).

These three areas have been subjected to further surveys and it is now possible to report on perennial changes which have taken place over a number of years.

The geographical and geological features of the three localities have been previously described (Walker and Richardson, 1955). The methods and rates of sampling, also previously described (*idem*) for each locality, have remained unchanged.

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[1]) Now with Department of Agriculture for Scotland.

[2]) Now with Imperial College of Tropical Agriculture, Trinidad, B.W.I.

Figure 1. Map showing the sublittoral regions considered in this paper.

Laminaria cloustoni has a perennial stipe which can grow for 10 years and even longer in rare cases, but of which the average age is 4 to 5 years in open sea habitats and 6 to 7 years in sheltered marine habitats around Scotland. The lamina is annual and usually shed about May (May cast) after a new lamina has been partially produced by intercalary growth at the junction of stipe and lamina.

During stormy weather, considerable quantities of the mature plants of *Laminaria cloustoni* are dislodged from the sea-bed and cast on to the beaches by rough seas or transported to other places by currents.

It is of interest to consider the various phases through which a crop of Laminariaceae may pass. It is possible to recognize three fairly distinct phases, each of which is directly influenced by three factors — (a) the number of plants per unit area, (b) the mean weight per plant, and (c) the algal cover of an area. The product of these three factors gives the total weight of a crop.

1. **A destructive phase** marked by a decrease in the population, as for example after strong gales, when large quantities of seaweed are cast.
(a) The number of plants decreases.
(b) The mean weight per plant decreases, as the larger plants are more vulnerable during strong gales.
(c) The cover decreases.

2. **A colonization phase,** when algae are recolonizing an area and the population is increasing.
(a) The number of plants increases as new young plants become established in areas previously cleared of plants during a destructive phase.
(b) The mean weight per plant decreases initially, since the addition of young plants brings down the value; with the addition of only relatively few young plants the value may remain unchanged or show small increases due to growth of mature plants.
(c) The cover increases as areas are colonized.

3. **A growth phase,** when the populations of newly established Laminariaceae are maturing.
(a) The number of plants may remain unchanged but ultimately a decrease will occur as the plants compete for light and space.
(b) The mean weight per plant increases as young plants approach maturity.
(c) The cover continues to increase.

Ultimately the maximum density and cover of the crop of a particular habitat will be achieved, although in nature the maxima may be reached only after the crop has been subjected to a series of destructive phases.

The three phases are unlikely to strike a balance each year; hence perennial crop changes occur.

The results of the surveys covering the three localities are summarized in diagrammatic form for easier comparison (the survey data and statistical analyses can be supplied on request).

The perennial changes of crops dominated by *Laminaria saccharina* LAMOUR have also been studied by extensive surveys around the island of Arran (accepted for publication, *Journal of Ecology*, 1955) and off north Shapinsay (WALKER and RICHARDSON, 1957).

Girvan to Bennane Head, South-West Scotland

Four surveys have been carried out in this locality, during April to May 1952, March to May 1953, March to April 1954, and March to April 1955, from low-water mark to 6 fathoms (11·1 m.) ordinary spring tides. Below 6 fathoms no Laminariaceae were found, as the sea-bed is one of sand or silt. The surveys were completed before the advent of the May cast.

The density (mean fresh weight for a unit area calculated on *all* quadrats, the plants being weighed immediately after leaving the sea), the algal cover of the area (the number of quadrats containing measurable quantities of Laminariaceae expressed as a percentage of the total quadrats), and the ratio of species (based on relative fresh weights) over 1881 acres (761 hectares) from low water to 5 fathoms are shown in Figure 2.

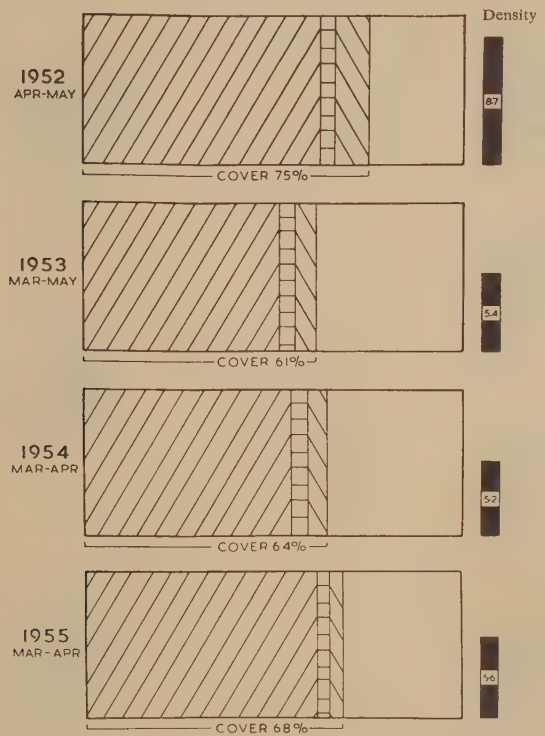

Figure 2. Girvan-Bennane Head. Density (based on all quadrats), cover, and ratio of species of Laminariaceae, low water to 5 fathoms.
/// = *Laminaria cloustoni* ☰ = *Laminaria digitata* \\\ = *Laminaria saccharina*

It will be seen that considerable loss of cover and density, amounting to 40% of the total weight of seaweed, occurred from 1952 to 1953; both *Laminaria cloustoni* and *L. saccharina* decreased. The greater part of this loss took place during a period of strong gales in September 1952 (unpublished data).

Between 1953 and 1954 the cover showed a small gain while the density showed a small loss, a sign of recolonization by young plants (Figure 4).

Between 1954 and 1955 this process continued, particularly in the deeper water where *L. saccharina* was more in evidence. The changes in cover and density (based in this instance on the mean fresh weight on a unit area of only those quadrats which contained some Laminariaceae) was general at all depths although the recovery at various depths was not uniform (Figure 3).

While the weight of plants decreased from 1953 to 1955, their number increased. It may be concluded therefore that recolonization was taking place but that the plants had still to attain the degree of maturity which the environment allowed.

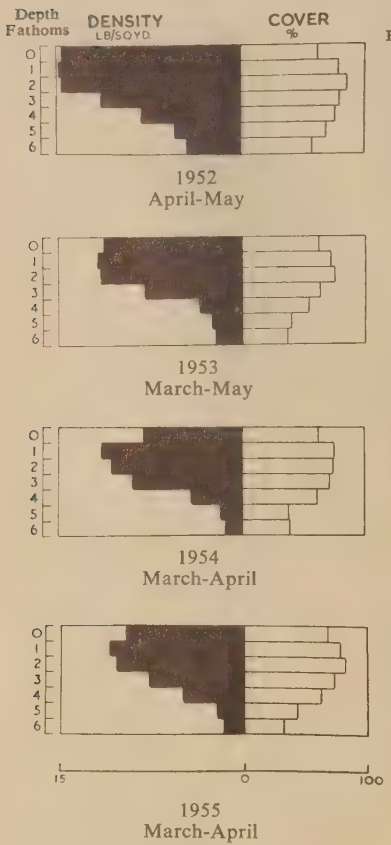

Figure 3. Girvan-Bennane Head. Density (based on quadrats with algae) and cover of Laminariaceae at 1-fathom intervals of depth.

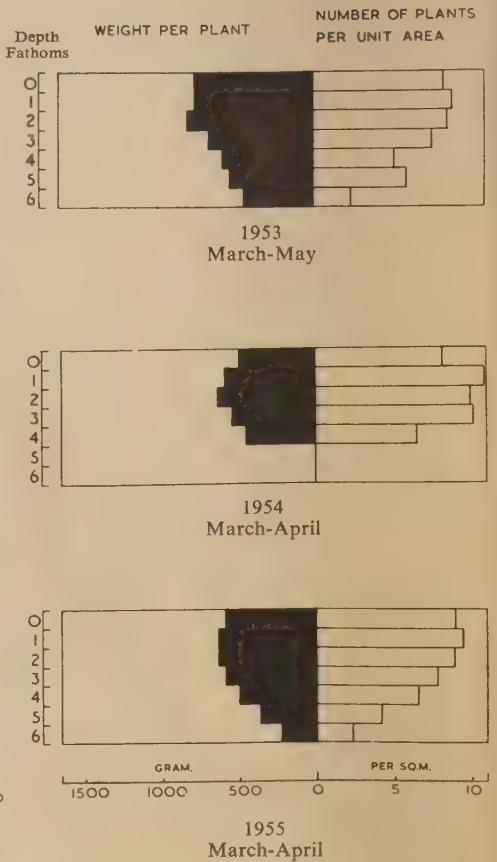

Figure 4. Girvan-Bennane Head. Fresh weight of plants of *Laminaria cloustoni* and their number per unit area at 1-fathom intervals of depth.

Dunbar to Fast Castle, South-East Scotland

Four surveys have been carried out in this region during September to November 1949, July to August 1952, July to September 1954, and August to September 1955, from low-water mark to 7 fathoms, ordinary spring tides. Below 7 fathoms the surface of the sea-bed is sand and gravel.

The density (mean fresh weight on a unit area calculated on *all* quadrats), the algal cover, and ratio of species over 1840 acres (744 hectares) from low-water mark to 5 fathoms are shown in Figure 5.

From 1949 to 1952, a very considerable loss, both in cover and density, was found at all depths. Between 1952 and 1954, recovery had begun and

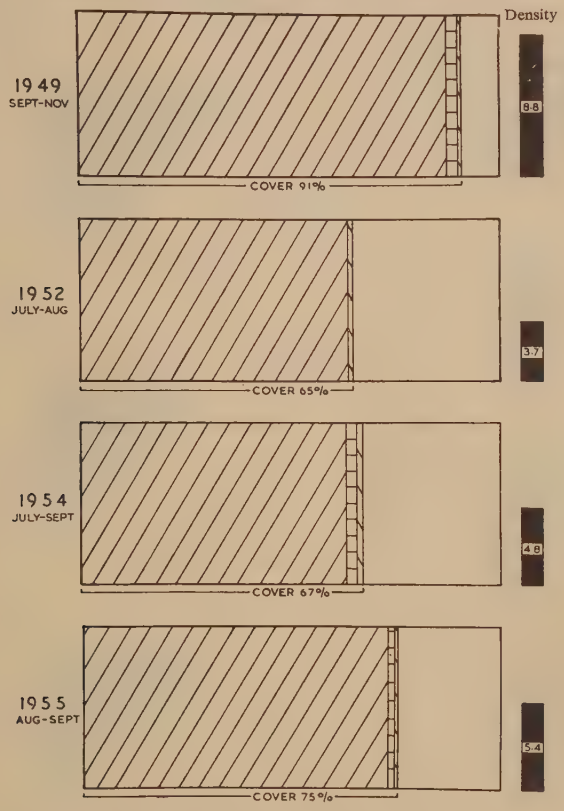

Figure 5. Dunbar-Fast Castle. Density (based on all quadrats), cover, and ratio of species of Laminariaceae, low water to 5 fathoms.
/// = *Laminaria cloustoni* ☰ = *Laminaria digitata* \\\ = *Laminaria saccharina*

continued into 1955, mainly by increases in cover (Figure 5). *Laminaria* in the shallower water underwent the greatest changes (Figure 6). From 1952 to 1954 the number of plants increased but their mean weight dropped; recolonization by young plants would account for this (Figure 7). From 1954 to 1955 recovery was consolidated.

Evidence was found that the movement of large quantities of sand takes place up and down the sublittoral zone of this locality; this movement would be a contributory factor in bringing about perennial changes in the seaweed crop.

Fraserburgh to Rosehearty, North-East Scotland

Four surveys have been completed in this region during September to October 1952, August to September 1953, October to December 1954, and

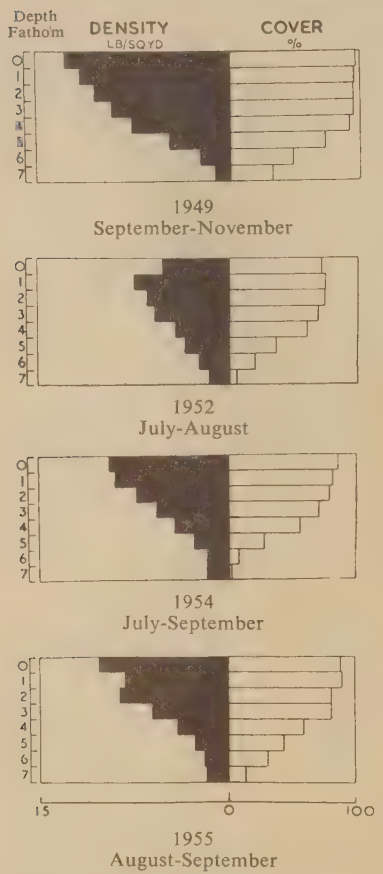

Figure 6. Dunbar-Fast Castle. Density (based on quadrats with algae) and cover of Laminariaceae at 1-fathom intervals of depth.

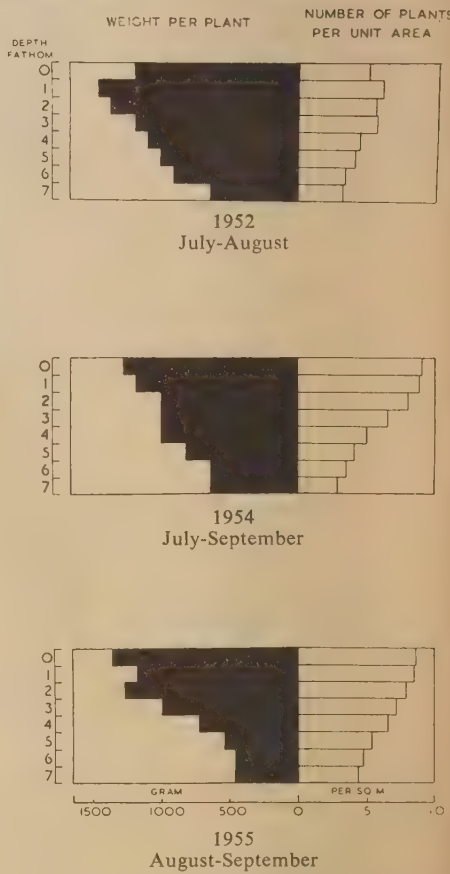

Figure 7. Dunbar-Fast Castle. Fresh weight of plants of *Laminaria cloustoni* and their number per unit area at 1-fathom intervals of depth.

August to September 1955, from low-water mark to 10 fathoms (18·5 m.), ordinary spring tides. Very little of the Laminariaceae were found below 10 fathoms.

The density (mean fresh weight on a unit area calculated on *all* quadrats), the algal cover, and ratio of species over 724 acres (293 hectares) from low-water mark to 5 fathoms, ordinary spring tides, are shown in Figure 8.

It will be noted that loss of both cover and density occurred from 1952 to 1953. From 1953 to 1954 complete recovery took place. It should be emphasized, however, that in 1954, owing to bad weather, the completion of the survey was carried over to a period when some casting of the weed had taken place. The recovery in density and cover in this area may be accounted

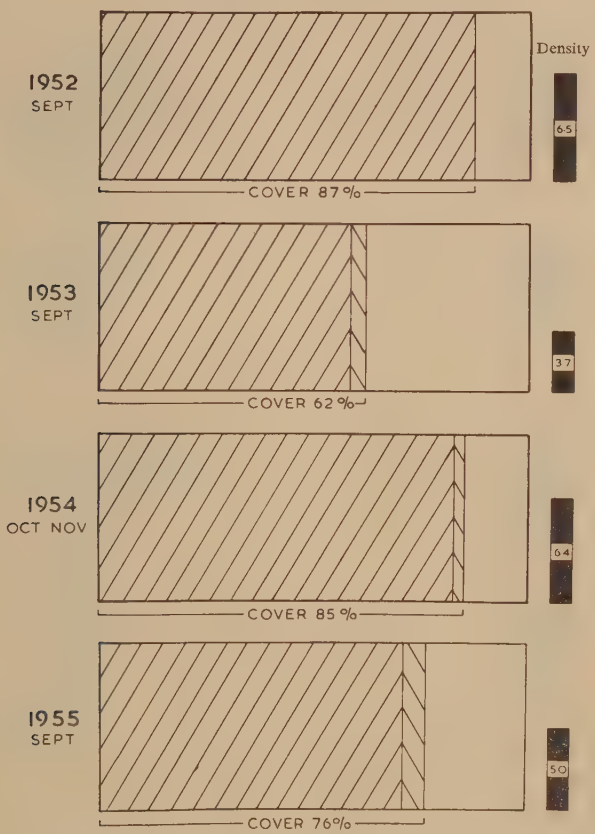

Figure 8. Fraserburgh-Rosehearty. Density (based on all quadrats), cover, and ratio of species of Laminariaceae, low water to 5 fathoms.
/// = *Laminaria cloustoni* \\\ = *Laminaria saccharina*

for partly by the presence of mature plants brought in by currents from other localities.

Between 1953 and 1955, recovery was certain; the true comparative figure for 1954 is probably intermediate. A study of changes of plant weights and numbers (Figure 10) lends support to this conclusion.

Statistical analyses of the 17,000 quadrats covered by the 12 sublittoral surveys above have been completed. The coefficients of variation of the samples from 1-fathom intervals are plotted in Figure 11. This statistic is useful when comparing various means having different standard deviations. The coefficients of variation covering depths from low water to 5 fathoms, which takes in all 12 surveys, show a trend towards increased variation with increased depth.

In the above surveys, losses were recorded until 1953, after which recovery took place. These findings conform to the general pattern of the Laminaria-

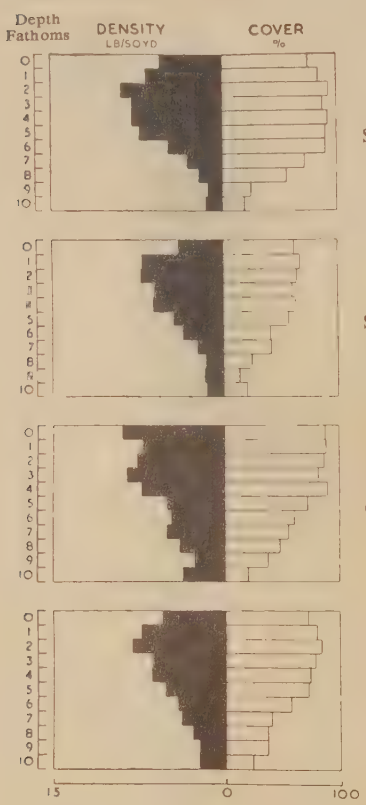

Figure 9. Fraserburgh-Rosehearty. Density (based on quadrats with algae) and cover of Laminariaceae at 1-fathom intervals of depth.

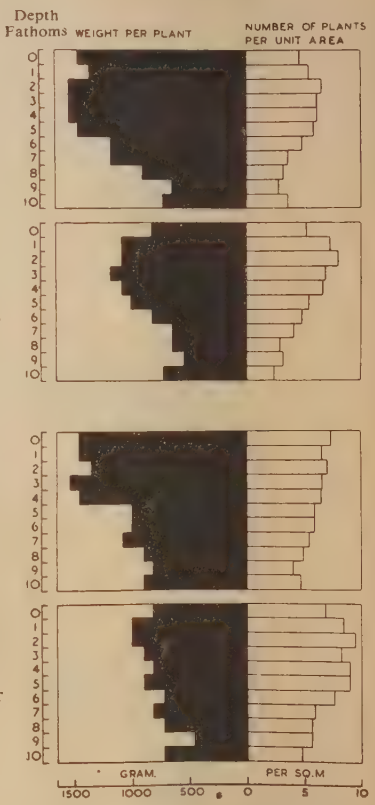

Figure 10. Fraserburgh-Rosehearty. Fresh weight of plants of *Laminaria cloustoni* at 1-fathom intervals of depth.

ceae around Scotland, where it has been found that the crest of density was attained in 1947, followed by annual losses until 1953, when the trough was reached; from 1953 recovery set in and has continued so far as records have been completed (1955). This trend is indicated by the following annual mean values of fresh weight per unit area of Laminariaceae found between low water and 5 fathoms inclusive, and computed from the data of 86 detailed surveys, for which 100,000 quadrats were measured: —

Year	lb./sq.yd. (×0.54 for Kg./m.²)	Year	lb./sq.yd. (×0.54 for Kg./m.²)
1946.....	9·1	1951.....	5·4
1947.....	13·4	1952.....	3·7
1948.....	11·2	1953.....	2·8
1949.....	8·0	1954.....	3·4
1950.....	5·0	1955.....	4·7

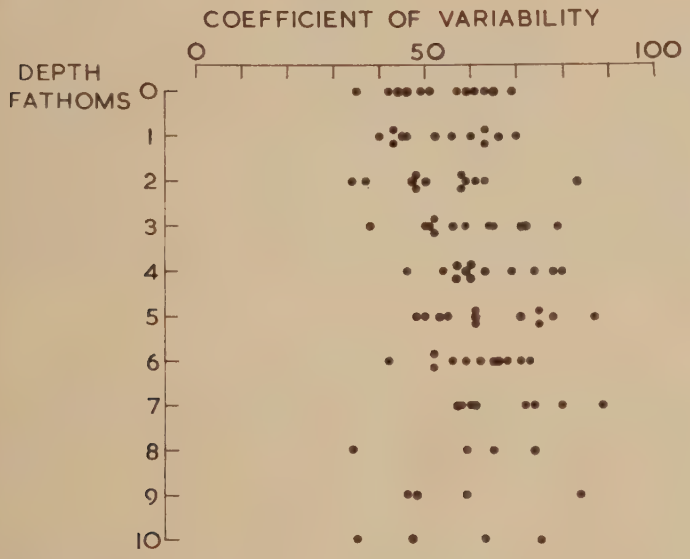

Figure 11. Coefficients of variability of 4 sublittoral surveys in each of three regions, where *Laminaria cloustoni* is the dominant species, at 1-fathom intervals of depth.

When the logarithms of these values are plotted, a crest appears at 1·1270 and a trough at 0·4470. Extrapolation backwards in time gives a trough in 1942 at the same level as in 1953, and forwards in time gives a crest in 1958 at the same level as in 1947. Ecological factors combining to produce an 11-year cycle would appear to be controlling the reproduction, colonization, and growth of the Laminariceae as it proceeds through the three phases set out above.

This 11-year cycle of the laminarian crop shows a surprising degree of correlation with that of the cycle of sunspot activity over the corresponding period (Walker, 1956).

Acknowledgements

These ecological surveys are part of the programme of research at the Institute of Seaweed Research, and the results are published with the Director's permission. We thank members of the Institute Scientific Advisory Committee, under the Chairmanship of Professor E. L. Hirst, F. R. S., and of the Algological Advisory Committee, under the Chairmanship of the late Sir William Wright-Smith, F. R. S., and Professor T. A. Bennet-Clark, F. R. S., for their constructive criticism, and we also thank W. H. Newton, Esq., formerly of the Royal Greenwich Observatory, for supplying information on sunspot activity.

Synopsis

A study of perennial changes over a number of years in the crop of Laminariaceae, where *Laminaria cloustoni* is the dominant species, is briefly described. Three localities in the north-east, south-east, and south-west of Scotland have been selected for this purpose.

Changes in seaweed density, cover, plant weight, and numbers are illustrated by graphs. The changes were found to conform to a pattern general to the Laminariaceae around Scotland, where the maximum of density occurred in 1947; losses followed until 1953, and subsequently gains to 1955.

The changes appear to be in phase with the sunspot cycle during the last ten years.

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Researches in the U. S. S. R. on Baltic Herring and Cod

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Scientific investigations of the Baltic waters off the U.S.S.R. coasts have been in progress since 1946. During the period 1948–1950 the work was carried on by a fishery research team from the Institute of Marine Fisheries and Oceanography of the U.S.S.R. The results obtained by this group were published in a number of papers dealing with the biology of the main food fishes, in particular the condition of the stocks, the main purpose being to describe the general state of the fishing industry in the Baltic Sea. Since then, similar investigations have been carried out by the Latvian and Estonian branches of the Institute and by the Baltic branch in Kaliningrad. The Institute of Freshwater Fisheries has also taken part in the work in the Gulf of Finland and the Biological Institute of the Academy of Sciences of the Lithuanian S.S.R. has carried out researches in the Kurisches Haff. The Leningrad branch of the Oceanographical Institute has taken part in the studies of the hydrographical régime of the Baltic Sea.

These institutes observe the changes in the hydrographical conditions, regularly examine the stocks of food fishes, and forecast, if possible, future catches. To that end, the causes of the variations in the fish stocks are being investigated. To perfect our methods of fishery survey and to enable short-term forecasts to be prepared, we attempt to establish the normal distribution of the food fishes, their migrations, and the stability of their aggregations, in so far as these matters depend on external conditions including food resources. Records made with hydro-acoustic apparatus on aggregations of fish are analysed in order to determine the degree to which these records represent the actual density of the shoals in a particular area.

Table 1

U.S.S.R. catches in the Baltic Sea
(in thousands of centners)

Species	1950	1951	1952	1953	1954
Salaka (Baltic herring).....	474	555	625	644	830
Cod	422	451	491	278	460
Sprat	44	52	35	36	36
Flounder.....	22	29	30	24	22
Large semi-migratory and freshwater fishes: –					
Bream, pike-perch, and others	43	56	67	72	92
Small semi-migratory and freshwater fishes: –					
Smelt, roach, and others...	102	123	117	125	149
Salmonids.....	2	2	3	2	2
Coregonids.....	9	8	10	5	13
Others.....	8	5	7	–	8
Total	1124	1281	1385	1186	1612

Table 1 gives a general idea of the Baltic fisheries.

The catches consist mainly of salaka and cod, and these fish are accordingly given most attention in our researches. The aim of the present paper is to summarize the researches carried out by the scientific workers at the institutions mentioned above.

Salaka (Baltic Herring)

The spring-spawning Baltic herring provides the major part of the catch, not only in the eastern part of the Baltic, but in the whole basin; since 1946 the quantity caught has risen notably. The autumn-spawning Baltic herring occupied an insignificant place in the catches up to 1955, but in the autumn of that year their numbers increased somewhat, as the result of a rich brood in 1951. In the autumn and winter of 1951–52, conditions were very similar to those of 1937–38, when the autumn-spawning herring brood reached its greatest abundance.

Table 2 gives the catch of Baltic herring in various parts of the eastern Baltic.

In 1954 the yield of Baltic herrings was higher than in any previous year, the reason being the expansion of the fishery and the exploitation of new fishing grounds. Sharp variations in catch are characteristic only of the

Table 2

Salaka catches in the eastern Baltic
(in thousands of centners)

Year	All regions	R. S. F. S. R. North	R. S. F. S. R. South	Lithuanian S. S. R.	Latvian S. S. R.	Estonian S. S. R.
1950.....	472·0	60·1	172·3	1·7	69·6	168·3
1951.....	555·6	56·6	163·1	4·1	115·9	215·9
1952.....	624·5	64·0	127·6	5·1	179·8	248·0
1953.....	643·9	70·4	82·7	11·9	228·4	250·5
1954.....	830·1	81·7	134·9	24·4	272·2	316·9

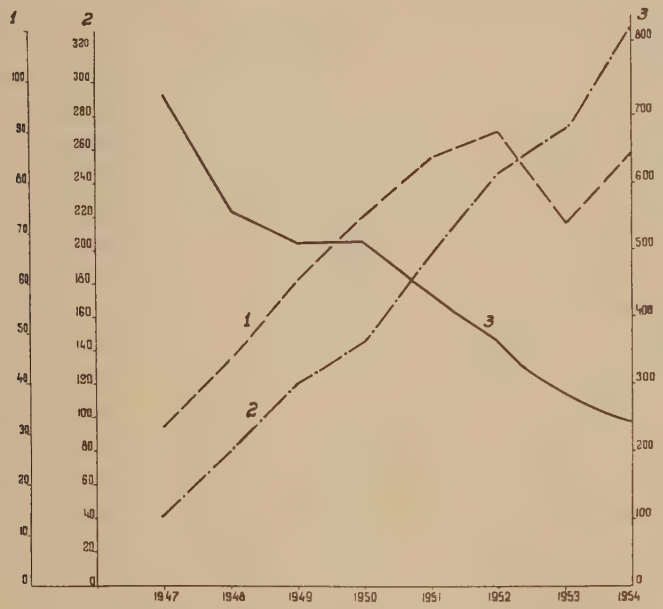

Figure 1. Trap-net catches in the Gulf of Pärnu from 1947 to 1954.
1 = total catch in 1000 cwt.
2 = number of trap-nets
3 = average catch per trap-net

southern Baltic, where salaka are caught off the mouth of the Vistula. Catches in the bay depend upon the presence of hydro-meteorological conditions favouring the entrance of Baltic herrings into the bay, and upon recruitment to the stock. It should be noted that the majority of the Baltic herring which enter the bay are spawning for the first time.

The main fishing grounds for salaka are in the Gulf of Riga and Gulf of Finland, as well as the narrows between the Estonian islands. The increase in the catches of Baltic herring is due to the increased use of the big trap-net, designed by engineer V. F. KANIN. The fish caught by trap-nets set in the bays form the major part of the annual catch. Trawls are used mainly in the Gulf of Riga and to some extent in the open sea.

Trap-nets are also set up along the shores of the open sea, but they catch less there than in the bays. Localities affected by fresh water rich in organic substances are favoured by the Baltic herring for reproduction; the plankton, particularly plentiful in such regions, forms the chief food of the fry.

On some of the fishing grounds the number of trap-nets has reached the point above which no increase in catch occurs as the result of the addition of new units of gear. This is the state of affairs in the Gulf of Pärnu and the estuary of the Vistula (formerly the Frisches Haff), where the shoals of spawning fish are distributed more or less evenly over the grounds; the more

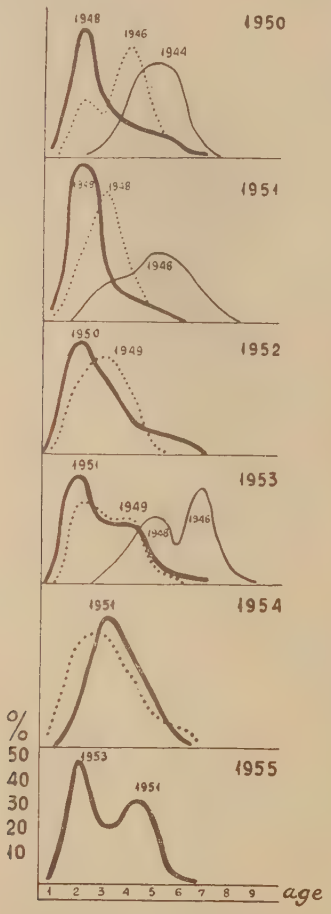

Figure 2. Age composition of the Baltic herring in the Vistula estuary, the Gulf of Pärnu, and in offshore waters. (After RANNAK, DEMENTJEVA, and SELEZKAJA.)
..... Vistula Estuary
——— Gulf of Parnü
——— Offshore Waters

numerous the trap-nets, the fewer are the fish caught per net. Figure 1 (after L. A. RANNAK) shows that though the number of fixed nets increased by 50%, the catch of salaka in the Gulf of Pärnu remained at the same level as in 1951. The young salaka remain in the bays (the Vistula estuary excluded) till their first maturity, and the majority of them spawn in inshore waters, where they are fished with trap-nets; the older they become, the farther they go into the open sea and the deeper the water in which they spawn. This phenomenon has been observed by many research workers who have studied the salaka. At 4 to 5 years of age, the Baltic herring leave the bays (e. g., the Gulf of Riga) for the open sea, and return only at the beginning of the spawning season and then in small numbers (about 25%). Most of the large fish stay at sea, where they are the object of a fishery which is being actively developed.

Forecasts of the catches of spring-spawning salaka and of the dates on which they may be expected in definite areas are based on differences between the age distributions of spawners in relation to the abundance of the various age-groups. Such forecasts have been successfully made by L. A. RANNAK for the Gulf of Riga.

The general condition of the stock of spring-spawning salaka is satisfactory, although recruitment was poor in some years, particularly 1947, 1950, and 1952. In 1946, 1948, 1949, 1951, and 1953, on the other hand, there were rich broods.

Figure 2 shows that particularly numerous year-classes appear first in the bays, and are not found at sea until some years later. This allows the occurrence of poor broods to be recognized at an early stage. For instance, the 1947 brood was almost entirely absent from the bays, and was also hardly noticeable at sea in 1953, according to the diagram of age composition. The herring hatched in the coastal areas of the Baltic Sea proper are not numerous.

Estimation of the numbers present in separate local populations, with different rates of growth shows that the variations in the salaka stock tend

to be common to all parts of the eastern Baltic. That is, if a rich or poor brood appears in the Gulf of Riga, it will usually, but not always, appear in the southern part of the Baltic.

Long-term forecasts of the catches are based on information on the relative strengths of broods, as given by the examination of the age composition of the stock and by sampling the younger stages. To discover both the present state of a fishery and also its future prospects is always kept in mind in our researches. These forecasts are made by the method elaborated by Prof. G. N. MONASTYRSKY after very careful study of a number of theories, set up by both Russian and other authors, which deal with the complex dynamics of a fish population.

G. N. MONASTYRSKY described various types of spawning populations according to the manner in which they adjusted themselves to external conditions effecting reproduction. The reproductive potential of the species is determined by the time of first maturity, duration of life, and other characteristics.

Basing his conclusions on extensive data G. N. MONASTYRSKY laid particular stress on external conditions in determining variations in the fish population through their effect on the viability of fish fry. No other factor affecting brood-strength is as important.

It follows therefore that fishing cannot cause large changes in the population structure of a fish which possesses a high reproductive potential, so long as the fishery does not develop to such an extent that it threatens to exterminate the population, or cut it off from its feeding and spawning grounds — so long, that is, as fishing does not reduce the number of spawners below the number which can occupy the whole spawning area. On the other hand, the number of spawners does not always determine the abundance of the brood. For the most part practical experience of the fisheries tends to support these views on the causes of the variations in the stocks of food fishes.

Extensive data have been obtained for the salaka from which it is possible to estimate the recruitment to the stock and so to determine its composition. To this end, since 1947 L. A. RANNAK has studied the development of the eggs and larvae of the Baltic herring in the Gulf of Riga. By recording the numbers of dead and living eggs and larvae in various stages of development over several

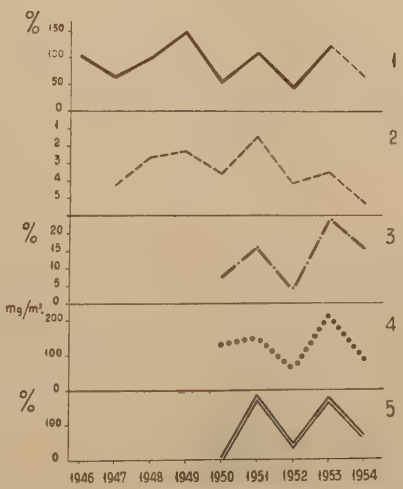

Figure 3. Relationship between (1) the brood strengths, (2) average number of larvae, (3) average number of yearlings, (4) quantity of plankton biomass in the Gulf of Riga, and (5) the discharge of the river Daugva. (After RANNAK and NIKOLAYEV.)

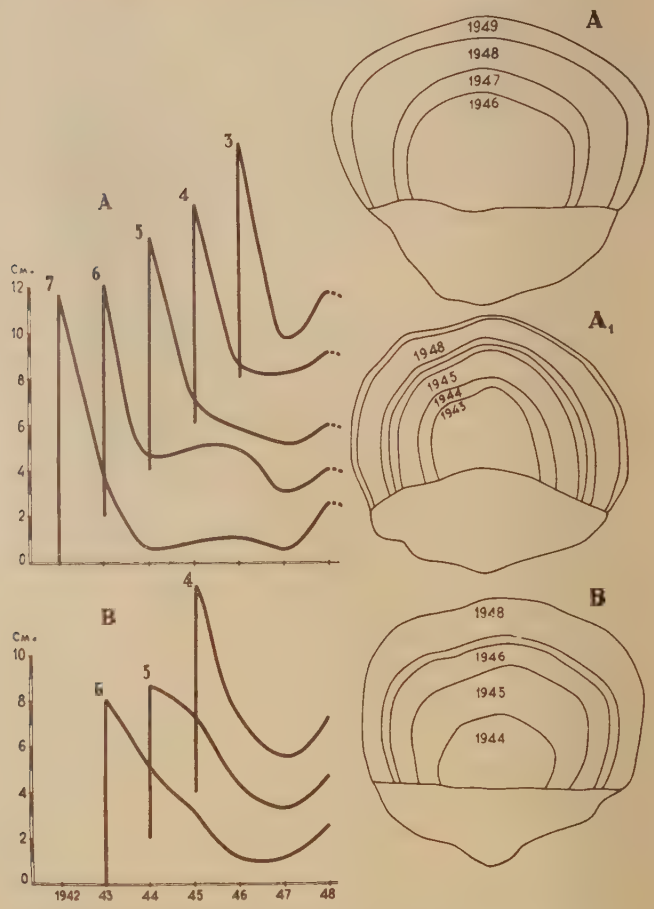

Figure 4. Growth increments of the Baltic autumn- and summer-spawning herring according to age and brood-year.
A = autumn-spawning herring, 3+ years, 1945 brood
A_1 = autumn-spawning herring, 6+ years, 1942 brood
B = spring-spawning herring, 5+ years, 1944 brood

years, it has been possible to recognize the conditions necessary to the survival of the brood and so to determine its relative strength.

The investigations made with this matter in view led to the conclusion that in recent years brood-strength has depended mainly on the survival of the larvae in transition to the stage of active feeding, in relation to the plankton biomass. This, in turn, is influenced (according to I. I. NIKOLAYEV) by the amount of water which the rivers discharge, and which enriches the

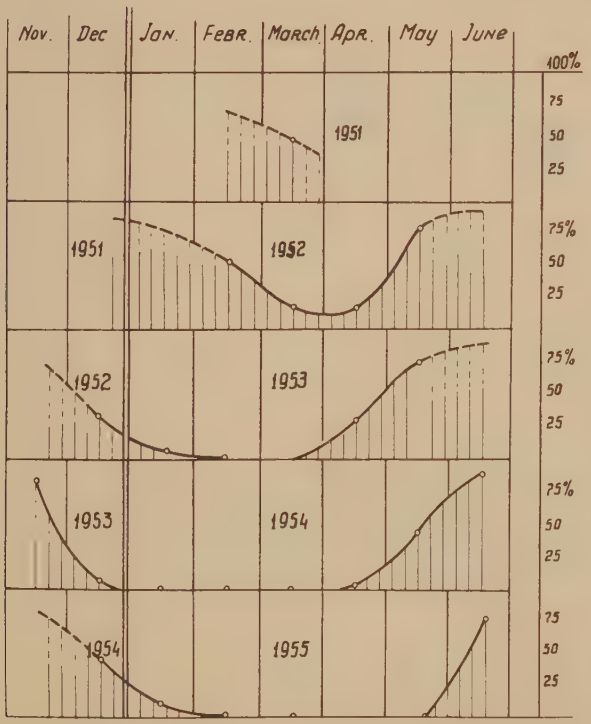

Figure 5. Duration of the non-feeding period in Baltic herring in the years 1952–55. (After Nikolayev.) The shaded area indicates the number of feeding fish.

waters of the gulf. Figure 3 shows the relation between the number of larvae, production of fry, size of population, plankton biomass, and river discharge.

The growth-rate in Baltic herring is one of the essential bases for forecasts. It determines the numbers which in the first years of life reach maturity and enter the spawning stocks. We know, however, that differences in growth-rate within a local population are so great that the average size of an age-group varies widely (up to 3 cm.).

Growth was slowest in 1947 and 1952, both cold years. H. Alander observed the same phenomenon in the cold years of 1940 and 1942. On the contrary, in warm years (e. g., in 1948 and 1951) the Baltic herring grew well. This indicates, firstly, that the higher temperatures favour the development of food, and, secondly, that feeding is more intense during warm years; that is, the rate of food assimilation increases up to a specific limit for each species. Changes in growth-rate are distinctly reflected in the width of the yearly zones on fish scales. Figure 4 shows a zone of slow growth in 1947 in the scales of fishes of various sorts and sizes. It is accordingly clear that more

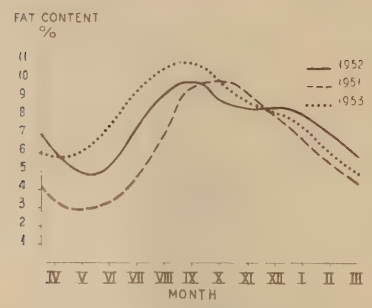

Figure 6. Change in fat content in Baltic herring in the Gulf of Riga from 1951 to 1953.

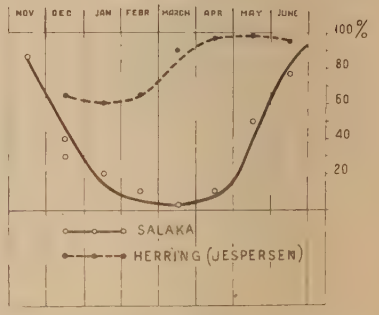

Figure 7. Percentage of non-feeding Baltic herring in the southern and central Baltic. (After NIKOLAYEV.)

general causes exist for variation in growth than feeding in regions providing differing quantities of food.

The growth and fatness of salaka depend also on its feeding during autumn and winter. The data collected by I. I. NIKOLAYEV, who counted the percentage of feeding and non-feeding fish present during this period, show that in warm winters, such as that of 1951–52, Baltic herring do not stop feeding (Figure 5). The herring caught in the following spring (1952) had the highest growth-rate.

In severe winters, especially in the winter of 1953–54, very many non-feeding salaka were recorded. It should be noted that in the autumn of 1954, as in 1951, the salaka continued feeding longer than usual. This may also affect the quantity of fat formed. As the diagram prepared by the Latvian Institute shows (Figure 6), the percentage of fat was higher in 1952 than in previous years. In the autumn of 1955 the fat content of autumn herring reached 16%, as against 9–10% in the previous years. Thus data on winter feeding, obtained by NIKOLAYEV's method, may indicate to the fishing industry the degree of fatness to be expected during the coming season.

The number of non-feeding individuals present is a good indication of the differences between the growth-rates of local populations of salaka in the Baltic. According to I. I. NIKOLAYEV (Figure 7), feeding intensity is low in December and May, while in February, March, and April it ceases almost completely; according to P. JESPERSEN, however, the southern salaka feeds all the year round. Thus the better growth of the southern salaka may be explained by the differences between the feeding régimes peculiar to the various regions.

Cod

Evaluation of the age composition and relative strengths of brood from the data on catch per unit of gear in different districts and at different seasons constitutes the main lines of the research on cod.

The increasing saltness of the Baltic, which started some 20 years ago, and which has caused a marked increase in the cod stock, is still in progress.

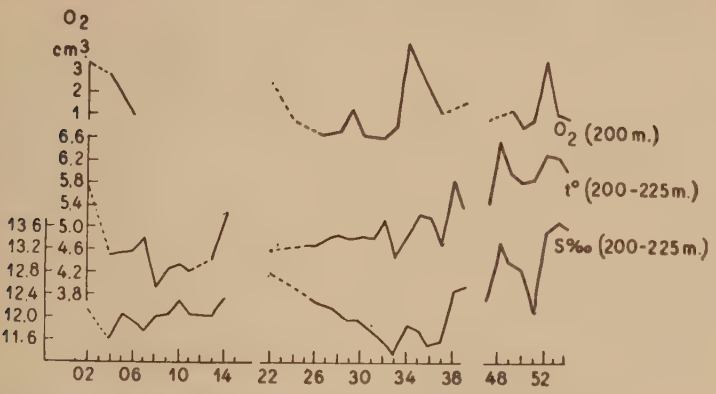

Figure 8. Long-term variation of temperature, salinity, and oxygen content in the bottom water-layer (200–225 m. depth) in Gothland Deep. (After Soskin.)

From the data obtained by I. M. Soskin over many years, it appears that variations in salinity, temperature, and oxygen content of the bottom water layer in the Gothland Deep at a depth of 200–225 m. have proceeded in the way shown in Figure 8. Both temperatures (Table 3) and salinity have exhibited a general tendency to rise since the early 'thirties.

Table 3

Average water temperature in Gothland Deep

Depth m.	Years 1904–11	1922–29	1932–39	1947–54
150–200	4·38	4·80	5·16	5·68
200–225	4·39	4·62	5·11	6·02

I. M. Soskin points out that the highest bottom temperature of 6·5°C. occurred in 1948. A powerful inflow of salt water took place in 1937–38, 1947–48, 1951–52, and probably at the beginning of the second world war. Soskin considers the effect of atmospheric pressure on the water exchange through the Belts and the Sound to be mainly responsible for the present conditions. The variations in the flow through these waters as well as a sharp rise in the salinity of the deep compensation current in the Kattegat are evidently of great significance. The long-term variations of salinity in the bottom layer on the Darsser Ridge are shown in Figure 9. This diagram is based on observations made at the "Gedser Rev" lightship up to 1938. The rise of salinity in the inflowing current did not of course immediately become evident over the whole of the Baltic.

Although the average annual discharge of the rivers into the Baltic fell during the period in which salinity rose, the general effect of the freshwater run-off on the salinity of the sea water is of secondary importance, according to I. M. Soskin. This view is borne out by the fact that the long-term changes

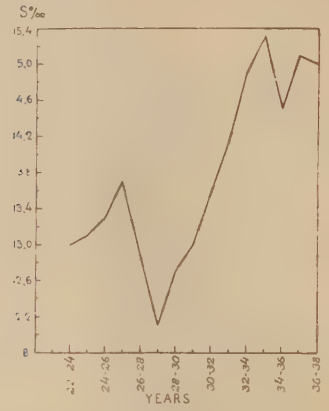

Figure 9. Mean salinities in the 10–15 m. water-layer at the "Gedser Rev" lightship over the period 1922–1938.

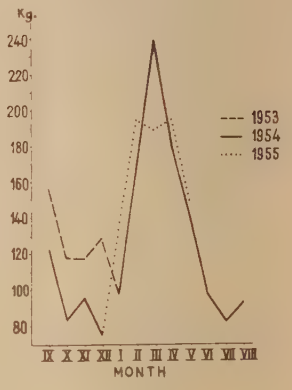

Figure 10. Average catch of cod per 1-hour trawl haul in two successive "biological years".

of salinity in the deep layers of the central Baltic and the Gulf of Finland are much greater than those occurring in the surface layer.

These features demand our special attention and call for new researches, and the development of the cod fishery will depend greatly on our efforts in this direction. Closely related to these problems is the appearance in the Baltic in recent years of warm-water and salt-water species of fish, together with their food organisms. This phenomenon is discussed by I. I. NIKOLAYEV in his work on the Baltic Sea.

At present most of the cod caught are taken by trawl. The Estonian and Latvian fishermen mainly use lines, but the line fishery contributes very little to the total catch.

Besides its prolonged spawning period the Baltic cod has another peculiar feature; being a cold-water form it feeds most intensively during autumn and early winter (according to A. T. SHURIN), and as a result the most rapid growth occurs in this period, as has been shown by G. I. TOKAREVA. Moreover the stock on which the commercial fishery rests is built up in this season. Figure 10 shows the relative sizes of the stocks in two successive "biological years", according to the average catch per 1-hour haul, and it can be seen that the cod were less numerous in 1954–55 than in the foregoing year, as a result of the smaller brood in 1951. This brood was particularly poor, as the age composition of the stock shows (Figure 11); in 1954, 3-year-old cod (1951 brood) were very poorly represented as compared with other broods contributing to the commercial fishery at the same age. Accordingly the catch was somewhat lower than usual in autumn 1954 and spring 1955[1]).

In recent years, the question of the decline in the Baltic stock has been

[1]) The data on age composition and of the average catch of cod from 1953 onwards were collected by A. PRIEDITIS.

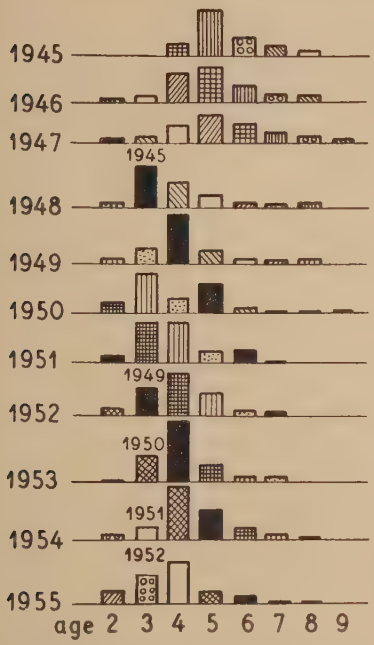

Figure 11. Age composition of the catches of cod made during the spawning periods in the years 1945–1955.

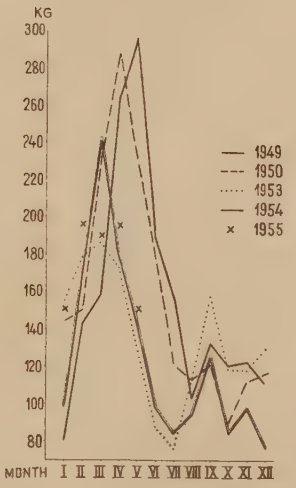

Figure 12. Average catch of cod per 1-hour trawl haul.

repeatedly discussed in connexion with the relatively smaller catches prevalent since 1951. Figure 12 shows that the yield of the cod fishery has in general fallen in the last few years and that the maximum catches of the first half-year are now taken very early in the year. The cause is probably to be sought in the earlier onset of maturity in the cod and the earlier spawning periods, resulting from the higher temperature of the water of the bottom layers (Figure 8).

However, smaller average catches do not, in our opinion, indicate a decrease in the stock itself, because, firstly, the fall in the catches may be temporary, since they may be caused by the presence of one or two poor year-classes, as was the case in 1955 (Figure 11); and, secondly, the fall in the average catch per 1-hour haul occurred mainly during the spawning season, not in the feeding or wintering periods (Figure 13). This suggests that the decrease in the catches may be attributed to a wider dispersal of the spawning shoals over the ground, as a result of the growing salinity of the deeper water layers, and was not caused by a reduction of the stock. This view is supported by the fact that in 1954 large and medium fish were caught again in large quantities.

The extension of the spawning grounds is illustrated in Figure 13, which shows the depth of the $10^0/_{00}$ and $11^0/_{00}$ isohalines in different years. According

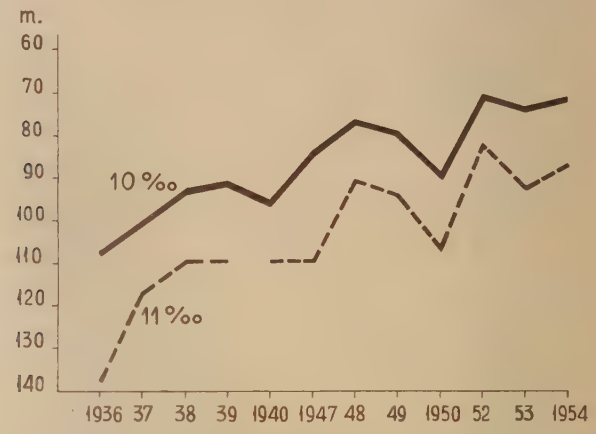

Figure 13. Depth of the 10 ‰ and 11 ‰ isohalines in Gothland Deep. (After Soskin.)

to R. Kändler, these are the optimal salinities for reproduction in the cod and for survival of the larvae. The gradual widening of the zone of high salinity in Gothland Deep may be noted.

The third and last cause of the fall in yield is to be found in an intensive fishery for young cod 25–30 cm. in length. It might seem at first sight that given a large stock, the capture of undersized cod could not greatly affect the population. They are, however, caught in such numbers that a considerable part of the catches consists of small, immature fish, consequently the weight of the catch was low, despite the great number of fish taken. The possibility of the weight of catches being increased through new recruitment has become limited, since the numbers of large fish in the catches are decreasing, as can be seen in Figure 11, which shows the age composition of the spawning stock. Therefore the suggestions made by Poland and other countries for restricting the fishery for small cod are of great value. Owing to the high reproductive capacity and the early onset of sexual maturity in the Baltic cod this measure would bring about a rapid increase in the average weight of the catch. In some regions of the Baltic in which the water, enriched by the inflow of fresh water, favours an abundant production of food organisms, small cod congregate in great numbers. Restriction of fishing will at first greatly affect the production of fishery organizations operating in these regions. Nevertheless, rationalization of the fishery is urgently needed in order to maintain a cod stock of high quality.

Further investigations will be made with this object in view. Firstly, the distribution of small cod at different seasons will be more precisely defined. Secondly, the effect of changes in hydrographic conditions on the survival of early stages of cod and on the distribution of mature fish will be studied; and, thirdly, changes in the biomass of planktonic and benthonic food organisms will be studied and estimates made of the food supply of cod larvae.

Summary

The results obtained by a number of Soviet scientists, together with the author's own observations, have been used to show the development of Soviet fishing in the Baltic in recent years. The methods of investigation of the stocks are described and some biological data on Baltic herring and cod are given.

Strong stocks of herring and an increase in the number of trap-nets have permitted considerably larger catches of spring-spawning herring to be made. However, in the Gulf of Pärnu and the estuary of the Vistula, the rise in the number of trap-nets has already led to a reduction in the average trap-net catch.

The catch of herring in different parts of the Baltic can be predicted from a knowledge of the relative strengths of the year-classes, of growth conditions, and of the hydrographic conditions at the times of migration. Some year-classes, particularly those of 1946, 1948, 1949, 1951, and 1953, were rich. Studies of spawning are being made annually in the Gulfs of Riga and Pärnu. It has been found that in recent years brood-strength has depended mainly on the survival of the larvae in transition to the stage of active feeding, in relation to the plankton biomass. The latter, in turn, is influenced by the quantities of water discharged by the rivers.

Differences between the growth-rates of local populations of Baltic herring can be ascribed to the differences in the numbers of non-feeding fish present at certain seasons. The better growth of the southern herring may be explained in this way.

The catch of cod has fallen in recent years. This may be explained, firstly, by the presence of one or two poor year-classes (e.g., in 1955), secondly, by a wider dispersal of the spawning shoals over the ground, brought about by the rise in the salinity of the deeper water-layers (the major part of the landings consist of spawning cod), and, thirdly, by the development of an intensive fishery for young cod, 25–30 cm. in length, on the feeding grounds. The rationalization of the fishery for young cod is urgently needed in order to increase the weight of the catch. Being a cold-water fish, the Baltic cod feeds most intensively during autumn and early winter, and as a result the most rapid growth occurs during this period.

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Movements of Herring Shoals in Relation to the Tidal Current

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Introduction

In the laboratory, fish placed in a narrow channel of flowing water orientate themselves to head into the stream and try to maintain their stations relative to the earth. This reaction has been shown to depend mainly on optical stimuli, the movements of the fish being such as to maintain a stationary visual field. If the fish touches the bottom or the sides of the channel, contact stimuli may provide sensory clues as to its movement downstream, and under certain conditions it is possible that information may be given by the lateral line. Various aspects of the problems raised by the orientations of fish to water currents are discussed by FRAENKEL and GUNN (1940). While reactions similar to those seen in the laboratory have been observed in streams and rivers, very little is known about the reactions of fish to the currents in the sea, tidal or otherwise. It is still a matter for conjecture as to whether fish swim with or against the currents or take any notice of them at all. Information on this particular aspect of fish behavior is badly needed, as the reactions of fish to water currents are a fundamental part of MEEK's now well known contranatant theory of fish migrations, which has been restated by RUSSELL (1937). As more becomes known about the migrations of important food fishes such as the cod and herring, the almost complete lack of knowledge of their reactions to currents is becoming a stumbling block in a comprehensive attempt to understand their biology.

In December 1955, the Ministry of Agriculture, Fisheries, and Food's research vessels "Sir Lancelot" and "Platessa" carried out a joint cruise with the object of following the movements and distribution of herring shoals around and among the banks off Calais and of seeing if the behaviour

of the fish could be related to the currents, which are there mainly tidal. Some of the results dealing with the movements of the shoals in relation to the direction of the currents are given in this paper.

General methods

Both ships worked in the Calais region from 11. to 17. December, inclusive. During this period continuous radio contact was maintained between the ships, and radar and the Decca navigator system were used extensively in plotting their positions and those of fish shoals located by echo-sounding.

Both vessels used Kelvin Hughes M. S. 24 sounders, transmitting at 30 Kc./s. Identification of the fish shoals located by echo-sounding was a general one, in that it is reasonable to suppose that most of the traces observed in the Calais region at this time of year are due to herring. Whiting occur in this area in small quantities but there is no reason to believe that there was any confusion between the two. Sometimes a particular identification was made for us by French pair trawlers who were fishing herring alongside the research vessels and from the very same shoals on which the latter were working. One sample of fish collected from pair boats in Calais in the middle of the cruise was found to be in maturity stages IV and V (A. C. BURD, personal communication). It is therefore possible that the herrings in the area were fish which were not spawning at the time at which the work was carried out.

Movement of fish shoals with the currents

Preliminary echo-surveys were carried out by the "Sir Lancelot" and "Platessa" on 11. December between the Sandettié and Outer Ruytingen Banks. Fish traces were found between the banks and along the northern edge of the Ruytingen. The Outer Ruytingen forms a part of the complex system of banks off the Flemish coast whose origin and structure in relation to the tidal streams in the area have been studied by VAN VEEN (1936). In general, the banks lie in a north-easterly direction along the line of the tidal streams and are complicated by the presence of ebb and flood channels, in which the residual currents are in opposite directions. A conspicuous ebb channel, in which the residual current is south-westerly, exists along the northern edge of the Outer Ruytingen. The presence of this channel, which is bounded by the 10-fathom contour, can be seen in Figure 1. At slack water in the early morning of 11. December an echo-survey showed that the south-western end of this channel was full of fish. Later in the day, when the stream had set to the east, the south-western part of the channel was found to be clear of fish. Towards dusk, after the west-going tidal stream had ceased, the channel was again full of fish, which were receiving the attention of ten or more pairs of trawlers. There seems to be little doubt that the traces seen on the echo-sounder at this time were due to herring. Further echo-surveys that evening showed that there was very little movement, if any, of herring over the sides of the channel into the deeper water lying on the southern edge of Ruytingen towards the West Dyck. The ebb channel appeared to be

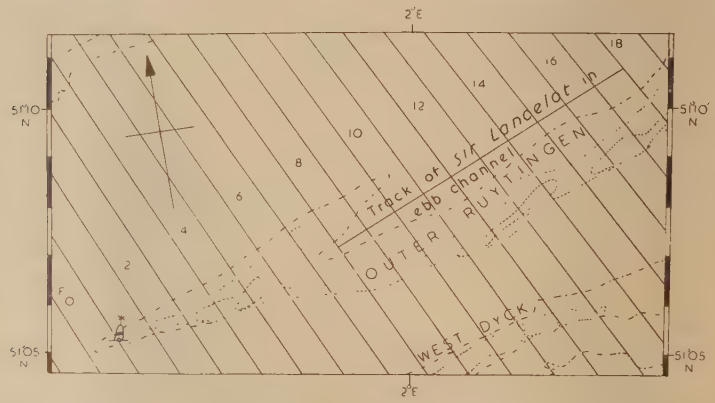

Figure 1. Track of echo-survey carried out by the "Sir Lancelot" on 12. December 1955. The diagonal lines represent the red Decca lanes.

acting as a trap in which herring moving into it on the west-going stream were caught and held until the stream turned and they were carried out again on the flood.

These preliminary observations suggested that it might be possible to show a movement of herring in and out of the ebb channel in relation to the tidal stream. The next day "Sir Lancelot" maintained a continuous echo-survey along the track shown in Figure 1 from 0835 hours to 2123 hours. This survey covered an east-going stream, a slack water, and a west-going stream. The distribution of echo-traces along the line of the survey was found by measuring, on the paper record, the proportion of the width of chart occupied by fish between successive red Decca lanes, which lay almost at right angles to the track of the ship. The results of this survey are expressed as a histogram in Figure 2, from which it can be seen that there appears to be movement of fish to the east on the east-going stream and a return to the ebb channel after the stream has turned to the west. The most reasonable interpretation of these results would seem to be that the fish are carried to the east on an east-going stream and to the west on the west-going stream.

Do fish stem the current?

The "Sir Lancelot's" work on 12. December seems to show quite clearly that herring shoals move with the current. However, such a long survey, while showing a movement of fish, does not provide the critical evidence from which it is possible to decide whether the movement was a passive one, or whether the fish were stemming the current or swimming with it. An attempt to answer this problem was made by the use of close surveys. From the data gathered during the joint cruise of the "Sir Lancelot" and the "Platessa", BOLSTER (1957) has been able to show that in the Calais area the herring shoals appear to be cigar- or spindle-shaped, with the long axis in line with the direction of the tidal stream. With BOLSTER's idea used as a

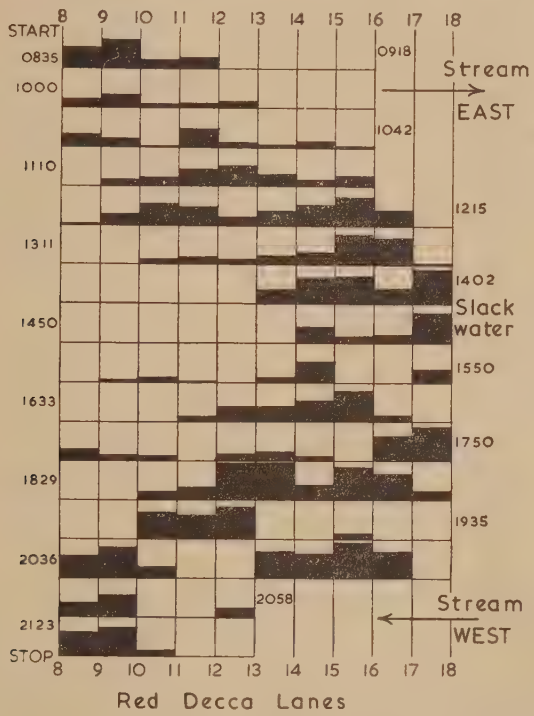

Figure 2. Histogram to show the quantitative distribution of fish traces along the line of the echo-survey carried out on 12. December 1955.

working hypothesis, both ships tried to follow the movements of individual shoals of herring and to see how the observed movements of the fish compared with that expected if they were being carried passively with the water. The method of approach is best understood by considering one close survey in detail. The one selected is that carried out by the "Sir Lancelot" on the morning of 15. December.

The essential details of this close survey are shown in Figure 3. The "Sir Lancelot" left Calais at 1125 hours and following the track shown in Figure 3, made contact with a herring shoal off the Ridens de Calais at 1207 hours. The stream was flowing strongly to the east. On establishing contact with the shoal, the "Sir Lancelot" turned south-west at 1211 hours and running out of the trace at (a), steamed well clear of it before turning about at 1245 hrs. Contact was re-established with the trace at (b) well to the east of the position at which it had been previously lost. Following the track shown on the chart, the ship again lost the trace at (c) and picked it up again on the return run at (d). The trace ran out at (e) and was not located again. The experience gained in other surveys in this particular locality on an east-going stream suggests that the shoal broke up into smaller units, which

Figure 3. Details of a close survey carried out by the "Sir Lancelot" on 15. December 1955. The presence of fish traces is shown by a thickening of the ship's track, which has been slightly opened up to avoid superimposition.

probably passed into the flood channel between the Outer Ruytingen and the West Dyck. The survey shows an eastward movement of the shoal with the stream. From the records of the times and Decca positions taken during the survey, it was possible to work out the apparent speed of the shoal relative to the ground. Estimates of the velocity of the tidal stream at the surface were made by comparing the ship's speed over the ground as given by the Decca navigator with the ship's speed through the water recorded by the Chernikeeff automatic log. The south-easterly wind, Beaufort Force 2–3, would not introduce any errors into these estimates. The apparent velocities of the east-going stream arrived at in this way are shown in Figure 4, and the principal results of the survey are summarized in Table 1.

Table 1

Summary of the results of the close survey

Trace	Time GMT	Red Decca position	Distance moved: sea miles	Speed at which shoal moved east: knots	Mean speed of east-going stream: knots	Movement of shoal relative to water
(a)	1234	15·4	1·7	4·0	5·8	West, 1·8 knots
(b)	1259	17·8				
(c)	1313	21·7	0·4	1·8	2·7	West, 0·9 knots
(d)	1326	22·3				
(b)	1259	17·8	2·1	3·3	3·0	Nil
(e)	1338	20·8				

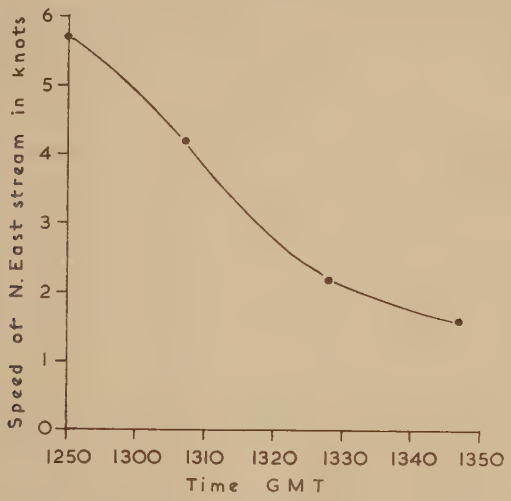

Figure 4. Speed of the surface water estimated during the close survey on 15. December 1955.

It will be seen that the movements of the shoal from (a) to (b) and from (c) to (d) were slower than that expected if the fish were being carried passively with the current, while the movement from (b) to (e) is at a speed close to that of the current at that time. The results could be taken as suggesting that in the first two cases, the fish were stemming the current at a speed of 1 to 2 knots. In the third case, the fish appear to have been carried along passively with the current. It seems quite reasonable to suppose that a herring can swim at 1 to 2 knots (0·5–1 m./sec.). According to GRAY's (1953) results with freshwater fish of similar size, it is probable that they can maintain a sustained speed of at least 2 or 3 knots (1–1·5 m./sec.).

However, care must be taken in accepting the results of this survey at their face value, as there are two important sources of possible errors inherent in the approach to the problem. Whatever the accuracy of the estimate of the current speed may be, it is a surface speed, and the water at the depth of the fish shoal, which in this instance lay between 5 and 10 fms., with the sea bottom at 14 fms., was almost certainly moving at a different speed. VAN VEEN's (1936) current measurements in the Straits of Dover showed that the maximum velocities were generally at the surface and that they fell off from top to bottom along the line of a parabolic curve,

$$v = a\sqrt[5]{h}$$

where v is the velocity at a distance, h, above the bottom, and a the velocity at 1 m. above the bottom.

However, a variety of factors, such as bottom features, wind, and proximity of the shore, may cause irregularities in current verticals, and it is little use

guessing at what speed the water might have been moving at the depth at which the fish lay. Measurements at the right depth are what is needed. Another source of error is in picking up the fish shoal again. Bolster (1957) has shown that the shoals in the Calais region are cigar shaped with their long axis in line with the stream. It is clear that if the track of the ship does not lie right along the main axis of the shoal, errors in estimating the distance that it has travelled over the ground might easily arise if it is picked up slightly to the left or right of the point at which it was lost.

The "Platessa" carried out several close surveys similar to that made by the "Sir Lancelot", but here again there is the possibility of the same errors. While the "Platessa's" results show movements of the fish shoals with the current, analysis of the data suggest that the fish might have been swimming against the current, drifting, or, on two occasions, swimming with the current.

It is clear that the evidence is such that it is not possible to come to any hard and fast conclusion as to whether herring do or do not stem the current. Critical evidence from close surveys can only be obtained by measuring the speed of the water at the depth at which the fish are swimming at the time at which the survey is being made. This is possible, but even with two ships there are obvious practical difficulties involved, and a good measure of luck will be needed if the observations are to be of real value.

Summary

1. Echo-surveys carried out in the Calais region in December 1955 showed that herring shoals moved in the same direction as the tidal currents. It is most likely that these observations were made on herring which had not yet spawned.

2. It was not possible to come to any definite conclusion as to whether the fish were stemming the current, swimming with it, of being carried along passively.

3. One set of results suggested that herring were stemming the current at a swimming speed of 1–2 knots, although they were being carried along with it over the ground.

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The Ratio of Shell to Meat in *Mytilus* as a Function of Tidal Exposure to Air

By

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Introduction

The source of calcium for shell deposition in marine lamellibranchs has been shown to be the sea water. Fox and Coe (1943) showed that the calcium available for this purpose from ingested food was not sufficient to account for shell growth, while Orton (1925) showed that shell growth could occur in the almost complete absence of food. Robertson (1941) stated that absorption of calcium ions from sea water was probable; Rao and Goldberg (1954) showed that such an intake to the tissues occurs. The utilization of calcium from this source in shell deposition has been shown by Wilbur and Jodrey (1952).

Rao (1953) suggests that the intake and deposition of calcium by molluscs is an automatic function, directly dependent on the exposure of the animal to the source of calcium, the sea water. There is support for this in the work of Wilbur and Jodrey (1952), who found that the amount of shell deposited by *Crassostrea virginica* was directly proportional to the period of exposure to sea water. Rao went on to show that in a sublittoral population of *Mytilus* the ratio of shell to meat was higher than in a littoral population. He suggested that the sublittoral population was exposed to the source of calcium (the sea water) for a longer period and thus greater accretions of calcium resulted. It has been our experience that, contrary to Rao's findings, bank mussels periodically exposed to air have, in general, thicker shells and less meat than mussels that are never so exposed, which would result in an increased ratio of shell to meat for these littoral mussels.

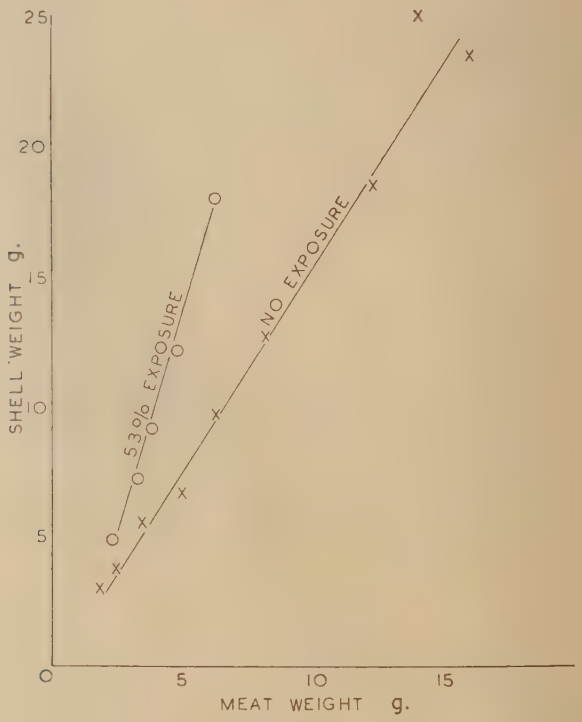

Figure 1. Showing the mean shell weight in relation to the mean meat weight.
o = ratio of shell to meat in littoral mussels.
x = ratio of shell to meat in sublittoral mussels.

Observations

To test these general observations a series of measurements was made on two groups of mussels of varying sizes from two tidal levels in the same area. Tidal recordings, which had been related to a permanent tide pole with an arbitrary zero (Figure 2), had been made in the estuary of the Conway River below the mussel purification tanks. This is a very sheltered position where wave action is at a minimum. The salinity drops to a low level at low water during and after periods of prolonged rainfall. Mussels are found in the area from a depth of about 20 ft. below low water extreme spring tides to a point above mean tide level. One group of mussels was dredged from a point 15 ft. below low water extreme spring tides and the other group was collected from the highest point at which mussels were found on the beach. From an analysis of tidal records over 14 days these latter mussels were found to have been uncovered for 53% of the time during that period.

The sublittoral dredged sample, which consisted of 73 mussels, ranging

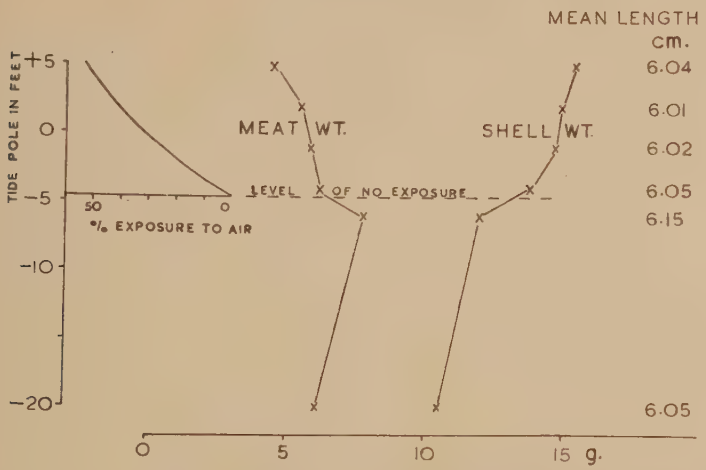

Figure 2. Variation of meat and shell weights in *Mytilus edulis* with variation of tidal level, with related percentage of time exposed to air. The levels are related to readings on a tide pole which had an arbitrary zero.

from 35 mm. to 89 mm. in length, was divided into nine length-groups, each containing between five and eleven mussels. The littoral sample, which consisted of 59 mussels ranging in length from 31 mm. to 69 mm., was similarly treated, being divided into 5 groups each containing between seven and twenty-one mussels. The shells and meat were both weighed wet immediately after opening. The mean shell weights are shown plotted against the mean meat weights in Figure 1. It can be seen that the mussels that had been exposed to air had the higher ratio of shell to meat.

To determine whether the decrease in ratio of shell to meat with decreased time of exposure to air was occasioned by an increase in meat weight or a decrease in shell weight, a series of samples was taken of mussels of approximately the same length at different levels on the beach and from the bed of the river. Four littoral and two sublittoral samples were taken. The shells and meats were allowed to dry on filter paper for two hours at room temperature before being weighed. The results, together with a curve showing time of exposure to air, are plotted in Figure 2. For a given length, meat weight increased with decreasing time of exposure, while shell weight decreased. The sublittoral samples from different depths showed little alteration in ratio of shell to meat with depth, but the sample from the greater depth showed a decrease in both shell and meat weight.

It has been shown (Dugal and Fortier, 1941) that an increase in the calcium content of the shell liquor occurs in oysters kept out of water for some days. To determine whether this effect was due to erosion of the shell or to a release of calcium from the tissues, as suggested by Jodrey (1952), and whether it occurred over a short period, samples of 50 mussels were taken from the highest level at which mussels were found on the beach, at

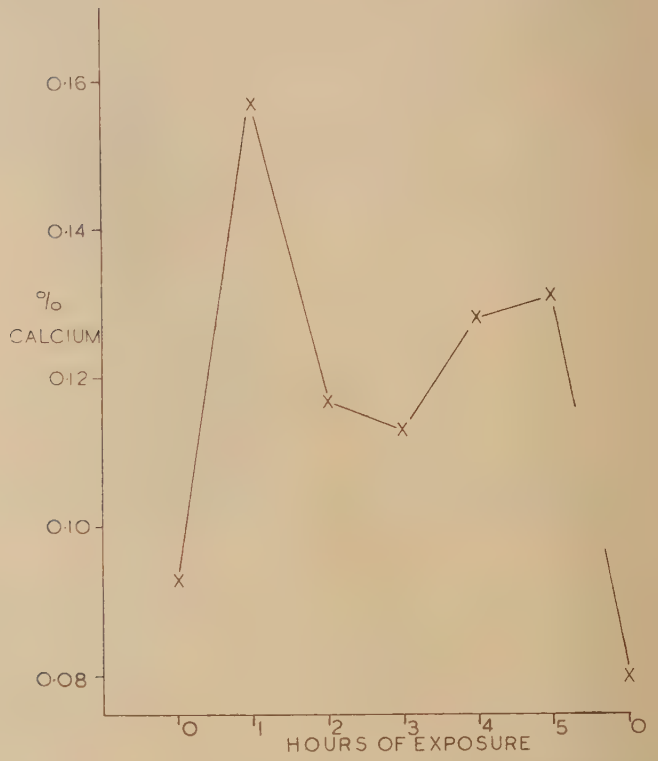

Figure 3. Calcium content of shell liquor and meat of *M. edulis* in relation to hours of exposure to air during a tidal period. Each point is based on a sample of 50 mussels and is the mean of duplicate analyses.

hourly intervals during that part of a tidal period in which they were out of the water. The pooled meats and shell liquor from each sample were analysed for calcium. It can be seen (Figure 3) that the percentage of calcium in the shell liquor and tissue is greater after the mussels have been out of water for some time than immediately after they are uncovered (0 hours exposure in Figure 3). On the following day a duplicate of the first sample was taken immediately after the mussels were uncovered, and this showed a return to a calcium level of the same order as that recorded immediately after they were uncovered on the preceding day. We believe it is probable that the result of the analysis for one hour's exposure is anomalously high; the duplicate analysis gave a much greater divergence in this sample than in any of the others. If the result for one hour's exposure is disregarded, the calcium percentage after a period of exposure to air shows a significant increase, at a probability level of 0·01.

Discussion

The ratio of shell to meat can only be changed by a factor which influences shell growth differently from that of meat. The factors that have been suggested as affecting shell thickness in a natural population of mussels are light, wave action, and tidal exposure to air.

Coulthard (1929) and Huntsman (1921) have shown that light affects the growth-rate, bright light reducing linear growth. This reduction appears to be a result of change of shape. That this could affect the ratio of length to weight of the shell is apparent, but it is unlikely that it would have an effect on the ratio of shell weight to meat weight because in each case the mussels have equal access to sources of food and calcium.

Fox and Coe (1943) suggest, and it is now generally known, that exposure to wave action results in slow growth and thicker shells. They also state that mussels living near or below low water have thinner and narrower shells than mussels from a higher level. In the area in which our observations were made there is not much wave action.

A reduction of salinity at low water would tend to have the same effect on the sublittoral mussels as exposure to air would have on the littoral mussels, tending to keep the mussels closed when salinity dropped below the tolerable level, thus lessening the differences between the samples. It is therefore reasonable to assume that the differences that exist between the samples are primarily due to differences in length of time of exposure to air.

In a population of mussels where length of time of exposure is the only variable, it would be expected that mussels exposed to air for half their life would be only half the size of mussels of the same age that were never exposed, because as the source of calcium was cut off, so would be the source of food; the net result would be that all the mussels had the same proportions with similar ratios of shell to meat. There is, however, another factor operating in the case of the mussels periodically exposed to air in that they are obliged to expend energy to maintain their basal metabolism while they are not feeding. This could result in a reduced proportion of meat in the mussels from the littoral part of the population, which would give higher ratios of shell to meat.

It can be seen from Figure 1 that the littoral mussels (53% exposure) had much higher ratios of shell to meat than the continually submerged mussels. From Figure 2 it can be seen that this higher shell/meat ratio for the littoral mussels is the result both of a reduction in the meat weight and of an increase in the shell weight for mussels of a given length. The use of reserves to maintain basal metabolism could explain the reduction in meat weight. The erosion of the shell (Figure 3) should result in a lighter shell for the littoral mussels, if no other factors were involved. Erosion of the shell is a function of the basal metabolism, and if the energy consumption during basal metabolism has a greater proportionate effect on the meat than erosion has on the shell, the net result can be expressed, in terms of energy, as a loss in the quantity of meat.

The schematic representation of shell and meat growth in Figure 4 demonstrates the way in which basal metabolism could result in the littoral

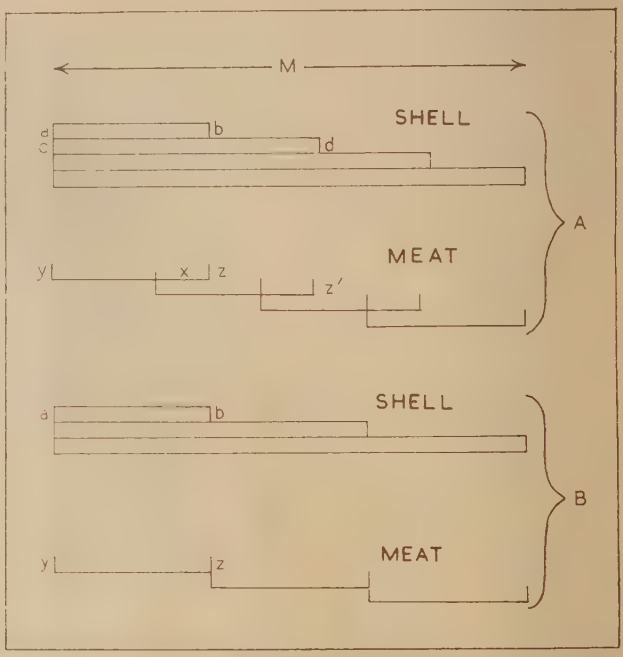

Figure 4. Schematic representation of the growths of shell and meat in (*A*) littoral and (*B*) sublittoral mussels, both having attained length *M*. The effect of basal metabolism on meat growth during exposure to air is represented by *x*. Shell growth (length and thickness) during one growth period is represented by *ab*, and meat growth by *yz*; in addition to the energy loss *x* in mussel *A* there will be a time interval between growth periods. On the assumption of 50% exposure to air and energy loss *x* for mussel *A*, the ratio of the age of mussel *A* to that of mussel *B* will be 8:3, and the ratio of their shell weights 4:3.

mussels having heavier shells than the sublittoral mussels. *A* represents a littoral mussel, *B* a sublittoral mussel, both having attained length *M*. There is evidence to suggest that shell deposition is continuous while the source of calcium is accessible to the mussel — that is, all the time it is covered with water. It is known that shell secretion occurs over the whole of the mantle. If we consider growth in periods of time, in the case of mussel *A*, shell growth *ab*, representing length and thickness, progresses simultaneously with the meat growth *yz*, while the mussel is covered. When the mussel is exposed by the fall of the tide, basal metabolism results in the consumption of reserves of energy, the loss of meat in terms of energy, in excess of the loss of shell by erosion, being represented by the resultant *x*. During the next period of immersion shell is laid down (*cd*), but since the energy lost through basal metabolism must be replaced to maintain the same mean condition, during the second growth period the quantity of meat grows to *z*, and four such growth periods are required to reach size *M*, and four units of shell thickness

are produced. In the case of the sublittoral mussel, where there are no losses due to basal metabolism while the animal is not feeding, size M is reached in three growth periods, with a consequent reduction in thickness and weight of shells. Thus, if we assume a 50% exposure for mussel A, it will take *more* than twice as long to reach the same size as a mussel that is always submerged. In addition to the loss x, there will be a time interval between growth periods equivalent to the growth periods. The ratio of the age of mussel A to that of mussel B will be 8:3, and the ratio of their shell weights 4:3.

The energy loss due to basal metabolism can be the limiting factor in the height above low water at which a suspension-feeding shore animal can grow. It can be seen that a point will be reached when the whole of the energy taken in whilst the animal is immersed will be needed to maintain the basal metabolism during exposure to air.

Coulthard (1929) showed that 50% exposure to air reduced growth in mussels (*M. edulis*) to a very low level and that mussels at that level had a mean growth during the period June–September of only one-sixteenth of that of mussels which were always submerged.

Summary

Mussels periodically exposed to air have been shown to have a higher ratio of shell to meat than mussels that were not exposed. Shell weight was found to increase, and meat weight to decrease, with increased time of exposure. A hypothesis to account for these differences is outlined. It is suggested that during the time that the mussels are closed through being out of water, the energy demands of basal metabolism reduces the meat more than internal chemical erosion reduces the shell.

A schematic representation is used to show how this could result in thicker shells in littoral than in sublittoral mussels.

It is suggested that the energy requirement of basal metabolism while the mussel is exposed to air could be the factor limiting the height above low water at which mussels are found on the shore.

Acknowledgements

We would like to acknowledge, with thanks, the part played by the Department of the Government Chemist in determining the calcium content of the mussel meats and liquors.

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Reviews

F. R. Hayes and **N. R. Beckett.** "The flow of minerals through the thermocline of a lake". Arch. f. Hydrobiol., **51**, 3, S. 391–409, 7 Abb. Stuttgart, 1956.

Die von den Verfassern in der vorliegenden Untersuchung gezogenen Schlußfolgerungen über den Transport anorganischer Ionen durch eine thermische Sprungschicht hindurch gehen von folgenden im Experiment gewonnenen Grundlagen aus. Die Verfasser benutzen zwei rechteckige Gefäße. Das kleinere besteht aus Kunststoff und besitzt eine Höhe von etwa 50 cm., das größere stellt einen Aquarientank dar und besitzt folgende Ausmaße: — Höhe 90 cm., Breite 90 cm., Tiefe 50 cm. In diesen Gefäßen, die mit Wasser angefüllt in einem Kühlraum bei 3 bis 5°C. gehalten werden, erzeugen die Verfasser durch Einhängen eines schwach heizenden Tauchsieders in etwa 10 bzw. 25 cm. Tiefe eine Sprungschicht mit einem Temperaturintervall von annähernd 20°C. Gibt man jetzt eine geringe Menge einer sehr verdünnten vortemperierten Salzlösung entweder direkt unter die Oberfläche oder direkt über den Boden der Gefäße zu der Ausgangslösung hinzu, so ergibt sich, daß die zusätzlichen Salzmengen sich nach verhältnismäßig kurzer Zeit (im kleinen Gefäß bei Zusatz zur warmen Oberschicht in 60 Stunden, im großen Gefäß bei Zusatz zur kalten Unterschicht nach 27 Tagen) nahezu gleichförmig in der Wassermasse verteilt haben. Nimmt man zunächst an, wie es die Verfasser getan haben und wie es die theoretischen Anschauungen erfordern, daß der Austausch durch eine derartig scharf ausgeprägte Sprungschicht, wie sie in den Versuchen vorliegt, praktisch unterbunden werden sollte, so lassen sich die mehrfach mit dem gleichen Ergebnis durchgeführten Versuchsreihen mit unseren bisherigen Anschauungen über die Austauschverhältnisse in Wassermassen nicht in Übereinstimmung bringen. Die Verfasser glauben daher, ihre Zuflucht zu einem neuartigen Erklärungsversuch nehmen zu müssen, indem sie als treibende Kraft für diese Vorgänge den "Diffusionsdruck" verantwortlich machen. Dieser muß auf Grund theoretischer Überlegungen zwischen zwei verschieden temperierten Wassermassen auftreten, und zwar würde er bei einem Temperaturunterschied von 20°C. in der Größenordnung von 5% des Gesamtsalzdiffusionsdruckes liegen. Da jedoch die Diffusionskonstante salzartiger Verbindungen im Wasser etwa 2 Zehnerpotenzen niedriger liegt als die als bereits sehr gering und daher als praktisch wirkungslos anzusehende

Wärmeleitfähigkeitskonstante des Wassers, so dürfte das Gleiche mit wesentlich größerer Berechtigung für die Diffusionskonstante Gültigkeit besitzen. Überschlagsmäßig läßt sich aus den bekannten Grundzahlen leicht errechnen, daß im Falle der reinen Diffusion 90 Tage nötig wären, bis ein Salz mit der Hälfte seines Konzentrationsbetrages um 10 cm. vorgedrungen wäre. Die entsprechende Zahl für eine Entfernung von 1 m. würde sogar 25 Jahre betragen. Hieraus geht ganz eindeutig hervor, daß der Vorgang der reinen Salzdiffusion bereits in unseren Versuchen im Tank praktisch ausscheidet, während er unter den wesentlich höheren Größendimensionen, wie sie in den natürlichen Gewässern vorliegen, völlig zu vernachlässigen ist.

Zweifellos liegt die Erklärungsmöglichkeit für das Ergebnis der obigen Versuche in ganz anderer Richtung. Und zwar ist anzunehmen, daß unser System sich nicht nur in der warmen Oberschicht sondern ebenfalls in der kalten Unterschicht durchaus nicht im thermodynamischen Gleichgewicht befindet, sondern daß sich durch Störungen an den kalten Außenwänden sowohl in der Sprungschicht selbst wie in der Unterschicht schwache Vertikalströmungen ausbilden, die für den langsamen Austausch der salzartigen Komponenten verantwortlich zu machen sind.

Die sinngemäße Übertragung der in den Experimenten festgestellten Ergebnisse auf die in einer wesentlich höheren Größenordnung liegenden Verhältnisse der natürlichen Gewässer dürfte daher nur mit größtem Vorbehalt aufzunehmen sein. Die inneren Zusammenhänge des Wärme- und Stoffaustausches im dreidimensionalen Raum, wie sie in den natürlichen Wasservorkommen in unserer Natur vor sich gehen, zählen zur Zeit noch zu den schwierigsten Kapiteln der Ozeanographie und der Limnologie.

Wesentlich wertvoller im Zusammenhang mit den von den Verfassern angestellten Untersuchungen über die vertikale Verteilung der Salzkomponenten in Seen scheint ihr Befund zu sein, nach welchem sie mehrfach ein intermediäres Salzgehaltsmaximum am Fuße der thermischen Sprungschichten gefunden haben. Dieser Befund deckt sich gut mit der analogen Erscheinung, wie sie häufig im Ozean angetroffen wird, wo das Auftreten eines Trübstoffmaximums im Niveau der unteren Sprungschichtgrenze eine bekannte Erscheinung ist (siehe J. Joseph, Deutsches Hydrographisches Institut, bisher unveröffentliche Untersuchungen).

K. K.

L. H. N. Cooper. "On assessing the age of deep oceanic water by carbon-14". Journ. Mar. Biol. Assoc. U. K., **35**, 2, pp. 341–54, 1 fig. Cambridge, 1956.

Nachdem die Altersbestimmungen mit radioaktivem Kohlenstoff an archäologischen Objekten in den letzten Jahren mit so großem Erfolg durchgeführt wurden, lag es nahe, diesen Gedanken auch auf die ozeanographischen Forschungen zu übertragen, um auf analoge Weise Aufschlüsse über das "Alter" der in der Tiefsee lagernden Wassermassen zu erhalten. Die ersten Messungen dieser Art, die von 1952 bis 1954 im Nordatlantischen Ozean ausgeführt wurden, ergaben als Alterswerte die erstaunlich hohen Zahlen von 1600 bis zu 1950 Jahren. Dies Ergebnis läßt sich mit den bisherigen Anschauungen über die innere Zirkulationsdauer von 100 bis 160 Jahren in keiner Weise in Übereinstimmung bringen.

Der Verfasser beschäftigt sich in der vorliegenden Arbeit daher mit den Gründen, welche vermutlich für diese unüberbrückbare Unstimmigkeit verantwortlich zu machen sind. Er kommt dabei zu folgenden Schlüssen: —

Zunächst kann man kaum damit rechnen, daß die Hauptbedingung für das einwandfreie Funktionieren der radioaktiven CO_2-Methode erfüllt ist, die darin besteht, daß ein annähernd stationärer Gleichgewichtszustand im CO_2-Haushalt zwischen der Atmosphäre und dem Ozean besteht. Die Gründe hierfür sind folgende. Aus der Gegenüberstellung der sowohl im Meere wie in der Atmosphäre vorhandenen Sauerstoff- und Kohlendioxyd-Vorräte ergibt sich, daß die Austauschvorgänge bei dem Kohlendioxyd 4000–6000 mal langsamer verlaufen als beim Sauerstoff. Für die Einstellung des Gleichgewichtszustandes, welches beim Sauerstoff beispielsweise einen Tag dauern würde, würde das Kohlensäuresystem demnach 10 bis 17 Jahre benötigen. Da selbst beim gelösten Sauerstoff im Ozean bisher keine Untersuchungen vorliegen, welche ein wirklich sauberes Gleichgewicht verbürgen, um wieviel weniger kann man ein solches daher von den CO_2-Verhältnissen erwarten.

Der zweite Punkt, der sich mit dem globalen CO_2-Kreislauf beschäftigt, zeigt, daß auf Grund der ozeanischen Gesamtzirkulation ein ständiger Entmischungsprozeß des atmosphärischen Kohlensäurespiegels am Werke ist und zwar dadurch, daß kaltes kohlensäurereiches Wasser aus den polaren Gebieten in die tropischen und subtropischen Regionen verfrachtet wird, wo es als aufsteigendes Tiefenwasser bei der Erwärmung an der Oberfläche des Meeres die überschüssigen CO_2-Mengen wieder an die Atmosphäre abgibt. Durch diese Vorgänge werden sich die vorhandenen, wenn auch zunächst nur kleinen Unterschiede in den Absorptionseigenschaften zwischen dem gewöhnlichen $^{12}CO_2$ und dem radioaktiven $^{14}CO_2$ immer weiter verstärken müssen, so daß ein gegenseitiger Vergleich nicht mehr einwandfrei ist.

Weitere Gründe für das "Versagen" der $^{14}CO_2$-Methode bestehen darin, daß der Vorgang des ozeanischen Wasserkreislaufes und die Vermischungsvorgänge unter den natürlichen Verhältnissen wesentlich komplexer und unübersichtlicher sind, als es zunächst auf Grund unserer erstmaligen, zur Zeit noch recht vereinfachenden Schemata den Anschein hat. Schon die Beantwortung der Ausgangsfrage, wann eine "Wassermasse" das Alter "Null" besitzt, läßt sich unter den komplizierten Verhältnissen des Konvektionsvorganges in den polaren Gebieten kaum einwandfrei lösen.

Unter diesen zur Zeit noch recht unklaren und unübersichtlichen Bedingungen, schlägt der Verfasser es als das Klügste vor, zunächst einmal voraussetzungslos weiteres und eingehenderes Untersuchungsmaterial über die Verteilung des radioaktiven Kohlenstoffs im Ozean zu beschaffen. Dabei muß aber von vornherein im Gegensatz zu den bisherigen Messungen besonderer Wert darauf gelegt werden, daß diese Werte nicht isoliert im Raume schweben, sondern daß es möglich ist, durch eine möglichst eingehende Klärung der ozeanographischen Gesamtsituation an Hand von physikalischen und chemischen Messungen die Bedeutung dieser ^{14}C-Werte im Gesamtmechanismus der ozeanographischen Zirkulation zu klären.

K. K.

G. Kurc. "Observations sur la dérive des flotteurs lancés par le 'Président-Théodore-Tissier' pendant les campagnes de 1951 à 1954". Rev. Trav. Inst. Pêches Marit., **20**, 3, pp. 225–61. Paris 1956.

This useful paper comes opportunely, in view of much recent argument about the relative merits of drift-bottles and drift envelopes. In some quarters the use of the easily transportable envelopes has been abandoned, but intentions exist to make large-scale liberations of them in the eastern Indian Ocean during the International Geophysical Year.

The author describes his bottles, which were of ordinary soda-water type ballasted as is customary, and sealed with waxed-in corks. The results under discussion in the paper come from liberations effected in 1951, 1952, and 1954, sometimes off the Bay of Biscay, sometimes on the western side of the North Atlantic, in the western English Channel, along a W.-E. line well west of the Channel, and across the North Atlantic in British latitudes. Returns in excess of one-third sometimes resulted from the sowings off the Bay of Biscay; in other cases the returns were of much smaller proportion, but adequate to provide interesting information.

We learn of one feature of the author's bottles which is novel to the reviewer and seems well worth copying. On one side of KURC's sealed-in questionnaire postcards a small but clear chartlet of the North Atlantic was printed. This covered the area stretching from 6° to 57°N. lat. over the longitudes 5° E. to 87° W. At the foot of the small chartlet, liberation details of the bottle concerned were given; thus a finder could immediately appreciate the overall travel which had been made good by the bottle retrieved by him. Though KURC emphasizes the dependence upon wind conditions of the bottle travels he studies, he makes no detailed analyses of the interrelationship. Asserting that no type of bottle hitherto used, whether of the coupled variety or that carrying a hanging metal vane, escapes wind influence, he supposes that no drifter in use in such experiments does so, except perhaps the plastic "Siphonophore" float of BOUGIS and RUIVO. The reviewer, who is not alone in doubting the virtues of this latter, is glad to see the results obtained with ordinary drift-bottles now presented by KURC, because they relate to liberations made over a wide area of the North Atlantic within a mere trio of years.

There is nothing particularly new in any of the findings discussed, but the author makes specific mention of the value which such bottle tracks as he establishes, have in connexion with the consideration of oil pollution on beaches. He has no difficulty in showing that oil wastes jettisoned anywhere in the North Atlantic within the latitude range of France and the British Isles could ultimately strand on shores of those countries, given a sufficient persistence of the oil patches.

In a recent paper published in the July 1956 issue of the *Journal of the Institute of Navigation*, the reviewer passed under consideration records of the travels of bottles and other message-carrying floats across the North Atlantic during long years past. This he did in part to serve arguments about possible oil-patch drifts to British shores from distances much further west than were concerned in the recent large-scale British experiments made with plastic envelopes dropped from aircraft. The overall bottle journeys now

recorded and discussed by KURC are, not surprisingly, in keeping with past knowledge that they would end on the shores of France, Britain, and other lands to the north. When inferences as to oil-patch drift are based upon experiences of plastic-envelope travels, one has (as it is wise to have) the gloomiest picture of the possibilities. That KURC's bottle travels permit the same directional inferences to be made regarding oil-patch travel shorewards from the spaces of the Atlantic is useful at this stage. It is likely that oil-patch travel would be something in between that of plastic envelopes and that of ballasted bottles in so far as dependence upon wind influence is concerned.

KURC's results attest a powerful surface-water indraught into the Bay of Biscay with numerous strandings on the Landes coast. Past experiments which reveal that fact are very numerous, but KURC cites only one paper from the 'nineties of the many by HAUTREUX *et al.* which exist. He does show that on occasion, there can be a north-going current near shore along the Biscay coast — a point much debated in the past in connexion with conflicting views held about the reality or otherwise of the Rennell Current.

Regarding the matter of strandings of bottles on Biscayan shores, the reviewer is surprised that KURC makes no reference to the important analysis of such occurrences published recently by ROUCH. In that analysis, ROUCH showed that from liberations made in the Atlantic over two distinct terms of years similar as to region and monthly sowings, there had always been most strandings in November and least in May. When discussing this work by ROUCH, the reviewer (in his article referred to above) cited a certain new German chart of representative monthly wind vectors as being entirely in keeping with ROUCH's finding.

Some of KURC's bottles rounded Ushant and travelled on up-Channel towards the North Sea, with the customary strandings on the west coast of Cotentin. It is worth mentioning that similar journeys are on record from the present-day sowings of plastic envelopes being made regularly on behalf of the French Hydrographic Office.

Of particular interest, because little shown by bottle experiments in the past, no doubt due to not meeting the same succession of meteorological conditions, are the recorded travels of bottles which journeyed from the western end of the English Channel all the way up the Channel to round Kent and strand on Suffolk shores.

This welcome paper would have been of enhanced value had the author undertaken a detailed study of the controlling wind conditions.

J. N. Carruthers

G. Tomczak. "Die Sturmfluten vom 20. bis 24. Dezember 1954 bei Cuxhaven". Deutsche Hydrogr. Zeitschr., **8**, 4, S. 145–56, 23 Abb. Hamburg, 1955.

M. P. H. Weenink. "De stormvloed van 21–24 December 1954. Een geval van resonantie". Kon. Nederlands Meteor. Inst., W. R. 56–002 (IV–013). De Bilt, 1956.

The days immediately preceding Christmas in 1954 were notable for two north-westerly gales which raged over the North Sea. These gales, their peaks

separated by an interval of some 36 hours, gave rise to two dangerous storm surges which are the subject of papers by TOMCZAK and WEENINK. This is not a remarkable coincidence, for the 1953 flood disaster in south-east England and the Low Countries sharply stimulated storm surge research in most of the countries bounding the North Sea.

Each author analyses the meteorological situations prevailing during the period; each computes (TOMCZAK for Cuxhaven, from wind observations at German light-vessels, WEENINK for the Hook of Holland, from isobaric distributions over the North Sea and English Channel) the surge that could have been predicted — given accurate weather forecasts — with the methods previously developed in their respective countries; each then proceeds to examine, and seek causes for, the discrepancies (which are by no means insignificant) between observed and computed surges. At this point the similarity between the two papers ceases.

TOMCZAK focuses attention on the surge heights at the times of astronomical high water tide, and out of 9 high waters finds "good" agreement for 2, "fair" agreement for 5, and "poor" agreement for 2. "Fair" agreement allows for a mean error of 15% of observed surge, the errors in these instances being attributed to the effect of winds over the northern North Sea, which are not allowed for in the method of calculation. "Poor" agreement denotes a mean error of 50%, and it is pointed out that on both occasions which are so classified, the wind field was changing rapidly enough to preclude quasi-stationary conditions (which the method of calculation assumes). In each case the synoptic situation over the North Sea was dominated by a deep depression moving in a south-easterly direction over the German Bight, a state of affairs which TOMCZAK has shown to be dangerous in its surge-raising potentiality, particularly if the passage of the centre of low pressure over the German Bight coincides with astronomical high water there.

TOMCZAK now supposes that the isobaric distribution responsible for the second surge peak (on 23. December), instead of thinning out when it did, continued to grow denser for another 3 hours and then thinned out. With this set of circumstances it is shown that a surge could have developed which, on top of the astronomical tide, would have raised sea-level at Cuxhaven 31 cm. above the highest ever recorded there before. This interesting deduction has no doubt been noted by those responsible for the sea defences of the German Bight coastline; in this connexion one wonders when meteorologists will be able (and bold enough) to fix upper limits to the strength and duration of northerly gales in the North Sea.

In WEENINK's paper the cause of the differences between observed and calculated surge is sought in the non-stationary wind field which prevailed during the period. It was first pointed out by THORADE in 1923 that observational evidence existed suggesting that storm surges in the North Sea might develop in an oscillatory manner, and PROUDMAN, DOODSON, CORKAN, NOMITSU, SCHALKWIJK, and others have since made progress in both the theory and the practical application of this approach to the response of a body of water to disturbing meteorological forces.

From an analysis of his calculated surge (the equilibrium wind effect) WEENINK is able to represent the major portion of the disturbance, covering more than 50 hours, by a pure sine term of period 36 hours, plus a constant.

This reduction of the equilibrium surge to a mathematical expression makes it suitable for entering into a formal solution for damped, forced oscillatory motion. The two unknown quantities in the result are parameters which represent a damping factor and a quantity related to the free period of the North Sea respectively. Numerical values are chosen for the parameters so as to give a best fit to the observed surges, the criteria adopted being the height of the second peak and the phase lag between observed and calculated curves. Re-computation by the non-stationary motion equation with the parameter values determined affords a decided improvement upon the equilibrium calculations. Moreover, valuable estimates are forthcoming from the analysis regarding the amount of damping in such surges and the free period of the North Sea. WEENINK's calculations apparently lead to a damping ratio (ratio of one amplitude to the next) for free oscillations of approximately 9 to 1, which is a little higher than that obtained by DOODSON and CORKAN for Southend surges. The free period of the North Sea is indicated as about 33 hours; this quantity must clearly be greatly dependent upon the orientation of the oscillation. The case studied is principally a longitudinal oscillation, and the estimate of 33 hours is within a few hours of values reached at the Tidal Institute in both pre-war and recent years, and by other workers also.

In conclusion, the period of the wind field and that of the North Sea on this occasion were in such close proximity that the twin surges represented a case of virtually complete resonance but for damping. Had a third gale occurred, satisfying the sine formula derived for the equilibrium wind effect, the third surge peak would have been no higher than the two preceding.

J. R. Rossiter

G. L. Clarke. "Elements of Ecology". 534 pp. John Wiley & Sons, Inc., New York; Chapman & Hall, Ltd., London, 1954.

This is a useful and interesting book, crammed with information; while it does not replace other text-books of ecology, it forms, owing to its unusual method of construction, a valuable addition to them.

There is more than one way of writing about ecology. One possible starting point is the animal and plant community; each type, whether of a tropical rainforest or the sea shore, is described in detail, and some understanding reached of the relations of the component species with each other and with their environment.

Dr. CLARKE works from the opposite end, the environment itself. A series of the earlier chapters are headed "Water"; "Temperature"; "Light"; "Oxygen and Carbon Dioxide", and "Nutrients". In each chapter a single environmental factor is studied exhaustively, together with its impact on all sorts of communities and species, whether terrestrial, freshwater, marine, plant, or animal. Later chapters deal with relations within and between species, with succession and fluctuations in number, and with the "dynamics of the ecosystem". A valuable aspect of this treatment is that the author never separates botany and zoology, but always keeps before the reader their essential interdependence in every ecological system.

One result of CLARKE's method is that hardly anywhere is a community considered as such. In one chapter there is a section on, say, the penetration of light into a forest and its effect on the stratification of the species, while in another chapter the stratification is related to humidity gradients. The author is, admittedly, fairly generous with cross-references in such cases, but even so it does remain difficult to keep any one type of community clearly in one's mind throughout the book. This is not meant to be an adverse criticism so much as a comment on the difficulty of dealing adequately with all aspects of ecology in one volume. An exception (as might be expected in a book by Dr. CLARKE) is provided by the plankton of temperate seas. In the relevant chapters there are sections on light and plankton, temperature and plankton, and so on, but in the last chapter there is also a good section on the dynamics of temperate plankton as a whole (here the work of BAINBRIDGE should surely have been mentioned in the paragraph on HARDY's theory of animal exclusion). Scattered through the book there are sections on fish numbers, age distribution in fish stocks, conditions of life in the deep sea, geographical distribution, and productivity. The treatment of the sea shore is disappointingly meagre, which is surprising in view of the rich variety of substratum in this habitat, and the way in which most of the environmental factors are changing so much, so often, and so quickly. There is one mistake which should be corrected in the next edition; the animals in Figure 10·4 are not *Adamsia palliata* and *Pagurus prideauxi*, but *Calliactis parasitica* and *P. bernhardus*.

Perhaps one final grumble may be permitted; the title could well have been "Elements of North American Ecology". Most of the examples come from the United States, and so do four-fifths of the references in the long bibliography. It is natural for an author to be more familiar with his own region than elsewhere, but for European readers the book would be even more useful than it is, had more un-American activities been taken into account.

When all this is said, however, the volume is a stimulating one, and is a welcome addition to ecological literature. It was built up from a course of lectures to honours students at Harvard University, and one cannot but feel rather envious of Dr. CLARKE's pupils.

John S. Colman

R. W. Ellis and **R. Jones.** "The whiting *Gadus merlangus* L. in the North Sea". Scottish Home Dept., Mar. Res., 1956, 2, pp. 1–25, 8 figs. Edinburgh, 1956.

Although the whiting is not the most important food fish of the North Sea, the problems connected with this species constitute an important part of the discussions on the North Sea fishery regulations. More biological data are needed for the whiting, and this paper gives much useful information.

The increased importance of the North Sea whiting fishery is shown by statistical tables, and a survey is made of the distribution of whiting of different ages. All ages are found throughout the North Sea, but whereas the 0- and I-group whiting are densest between latitudes 55° and 58°N., the centre of density of the older whiting is rather farther to the north. It is difficult to say whether this apparent northerly shift is due to a northerly

migration or to the effects of differences in distribution of fishing effort, fishing intensity being probably much higher on the southern than on the northern grounds.

A graph showing the brood fluctuations of the whiting shows that they correspond to some extent with the brood fluctuations of the haddock. Estimates of growth are compared with those given by earlier authors. From the considerable differences between these figures, it is concluded that variation is wide.

Whereas the chapters reviewed so far give clear-cut information on biological facts, the last chapter is much more speculative. Commercial statistics show that the landings of adult whiting in the years 1947–1952 were much higher than before the war, although the fishing intensity had decreased. Computations based on theoretical considerations show that the increase in yield per recruit to be expected from the estimated decrease in fishing effort agrees remarkably well with the observed increase in landings. The authors conclude that the increase in landings might well have been due to the decrease in fishing effort that actually took place. I agree with the authors that the results of the calculations should be accepted with reservation, not only because no data are available on the rejection of whiting at sea, but also because some of the other assumptions and estimates are only the best that can be made in the absence of reliable data and so may prove to be incorrect. Furthermore, the big increase of the industrial fisheries, which take both immature and mature whiting, has been entirely left out of account in the calculations, although the increase is mentioned in the introduction. The value of these calculations seems a little doubtful so long as so few data are available. In particular, more data on the distribution of fishing effort and on the migration of whiting are needed.

The paper contains one annoying error; in the graph of year-class strength (Figure 6) from 1937 onwards the data for haddock and whiting have been interchanged. This leads the authors to the erroneous statement that 1948, instead of 1949, was a good year for whiting brood. Notwithstanding these remarks, the paper is a valuable addition to the rather scanty literature on the biology of the whiting.

L. K. B.

G. Krefft, K. Schubert und **D. Sahrhage.** "Der augenblickliche Stand der Erforschung des Nordseeherings mit besonderem Hinblick auf die Frage seiner Überfischung". Arch. f. Fischereiwiss., **6**, 3/4, S. 141–88, 15 Abb. Braunschweig, 1955.

The paper under review is a contribution to the discussion of the problems of the North Sea herring fishery, more especially the "overfishing" question which has attracted increasing attention in recent years.

The North Sea herring stocks are discussed, and the conclusion is reached that there are three well defined sub-species in the area. Of these the autumn spawners form the main basis of the German herring fisheries. This group can be divided further into at least two sub-species, Bank herring and Downs herring.

For the Bank herring from the Dogger Bank and Fladen Ground comprehensive series of age analyses over a long period have been examined. The inquiry reveals only natural fluctuations in the composition of the stocks, and examination of the catch statistics (1910–1952) shows no sign of present overfishing. This investigation shows too that the Fladen Ground herring are usually older than the Dogger Bank herring.

For the Downs herring it is accepted that special conditions exist, and that overfishing might conceivably occur. The authors offer, however, an alternative explanation; they suppose that the herring stocks are shifting northwards as a result of temperature changes in the environment. It is implied that the increased growth-rate of the North Sea herring is due to this phenomenon and not to a decrease in the density of the stock. The older herrings in particular are supposed to be moving to more northerly spawning grounds; this tendency is shown by the Fladen Ground and the Dogger Bank herring, for example. An analogous phenomenon would then account for the lowering of the age of the Downs herring and the disappearance of 4-year-old fish.

The migrations of the herring in the North Sea are considered in the light of recent tagging experiments. The extensive Scottish and Swedish taggings in particular furnish strong evidence for the postulation of an anti-clockwise movement with a yearly cycle covering the whole North Sea for the Bank herring. The taggings have so far yielded no conclusive evidence as regards the migrations of the Downs herring.

The central issues in the discussion of the North Sea herring fisheries are, according to the authors, the effects on the stocks of (a) the introduction of echo-sounders, (b) the replacement of the drift-net by the trawl, and (c) the fishery for young herring.

Improvements in fish location devices result in the fishery gradually losing its seasonal character, and thereby being deprived of the preservative effect of the previous close seasons. The trawl, being the more efficient gear, takes heavier toll of the stocks than does the drift-net, and it also catches quantities of non-marketable herring, which are destroyed. A fishery for small herring in the open waters of the North Sea has recently been developed, mainly by the Danes and Germans. The catches, almost without exception, go to reduction plants. The crucial question is, Does this fishery on its present scale constitute a threat to the mature stock of fish? The German answer is that for the Bank herring, there is no evidence, and for the Downs herring, it is not necessarily a threat.

Olav Aasen

F. W. F. Morawa. "Laichen, Laichbedingungen und Laichplätze des Sprottes (*Clupea sprattus* L.), dargestellt auf Grund von Untersuchungen in der Kieler Bucht". Zeitschr. Fisch. u. d. Hilfswiss., 3, N. F., 4/5, S. 343–73, 20 Abb. Radebeul & Berlin, 1954.

The author begins by considering his own investigations in Kiel Bay, into the spawning of the sprat, the conditions for spawning, and the spawning grounds within the region. He then links his results with those from other

areas, and succeeds in making valuable contributions to the solutions of the questions he is dealing with.

After having described his own methods of investigation, he surveys the horizontal distribution of sprat eggs within Kiel Bay and points out that during the spawning season (May-July) a displacement of both the spawning area as a whole and of the centre of spawning from west to east occurs. In the Firth of Flensburg, however, the spawning area remains in one position. The movement of the spawning area is thought to be due to migrations of the sprat, but the author does not attempt to give any reason for these migrations. Can the migrations be explained by hydrographical changes or by an abundance of phytoplankton reducing the quantity of crustacean zooplankton available to the sprat? It is well known that the density of phytoplankton tends to show a negative correlation with the density of zooplankton. The occurrence of sprat eggs seems as a rule to be limited to the water layer above 15 m. where the salinity ranges between 15 and 20‰ and the temperature between 6° and 12°C. Spawning seems to be very much dependent on water temperature and usually begins over the whole area as soon as the temperature exceeds 6°C. Occasional drops in the water temperature seem to delay the spawning, at least locally. Even though the relationship between the number of eggs on the one hand and the temperature and salinity conditions on the other seems to be clear, the author emphasizes, certainly correctly, that it is difficult to define the exact correlation, as there are obviously other unknown factors which influence the spawning process. The investigations in Kiel Bay have also shown that the size of the eggs decrease throughout the spawning season when the salinity increases.

The author rightly draws attention to the fact that the 0-group of sprat occurs almost exclusively in the Firth of Flensburg. There may no doubt be different opinions as to the reason for this, but the author is inclined to assume that there is a connexion between this phenomenon and the great number of Scyphomedusae, especially *Aurelia aurita*, which occur just before spawning time. There can be little doubt that a considerable number of fish eggs and larvae are in fact devoured by these medusae, even though at present we have little positive evidence of this. The question deserves further attention.

The horizontal distribution of the larvae agrees largely with that of the eggs. As regards their vertical distribution, the larvae are found in the water layer above 10 m. depth, and the author agrees with the opinion that they remain in the surface layers both by day and by night. A maximum size of 6 mm. is reached in May.

The investigations also show that it is not possible to distinguish between the larvae of herring and sprat by the caudal pigmentation.

It must be emphasized that investigations like these, carried out in a restricted region, are of particular value, as they provide a good opportunity for close study of a great variety of problems.

Arvid R. Molander

N. A. Nilsson. "Studies on the feeding habits of trout and char in north Swedish lakes". Rep. Inst. Freshw. Res., Drottningholm, 36, pp. 163–225, 22 figs. Lund, 1955.

The investigations were carried out during the years 1944–49 and 1954 in Blåsjön, Ransaren, and Korsvattnet in northern Sweden. Nearly 2,500 trout and char were caught and the stomach contents of about two-thirds of them were analysed.

The results of the investigations confirm many of the findings of previous workers. For example, in Blåsjön the feeding habits of both trout and char vary with the season and also from year to year. As may be expected, the seasonal variations seem to depend on the seasonal variations of the fauna itself. During the ice-free season (June to mid-November), bottom food is more important to trout than it is to char, whereas the planktonic Entomostraca are of great importance to char, but of little importance to trout. On the other hand, hatching and flying insects (mainly Chironomidae pupae and terrestrial insects) are consumed by both species.

The annual changes in the feeding habits of the fish seemed to depend on changes in the organic production in the lake or other changes in the supply of food animals. For example, in 1946, which was the third of a series of dry years with very hot summers, the quality of the fish was high, and it was presumed that very high organic production occurred. In 1949, however, the summer temperature was exceptionally low, presumably resulting in low organic production. In that year the quality of the fish was low.

In 1947, the damming up of Blåsjön started on a restricted scale, and it is interesting to note the possible effect of this regulation on the fish and fish-food. As soon as the dam was completed and draining started, certain bottom organisms such as Pisidae and *Gammarus* decreased in abundance. At the same time, during the first year or so, the nutrients of new areas were made available, possibly causing an increase in the abundance of crustacean plankton.

In 1954, after four years of full regulation, there was a low consumption of bottom food by both trout and char.

The paper then describes the way in which the seasonal and yearly fluctuations in food organisms might influence the growth and condition of the fish. To express "condition" the author used FULTON's formula $W = \frac{L^3 C}{100}$, W being the weight of the fish, L the length, and C a condition coefficient. From the material available it seems that the condition of the fish depends on the rate of production of the lake and the amount of reserve food. Plankton is said to be less nutritive than the other types of food, and low condition coefficients are found in fish which depend on plankton as their main food. An account is given of the availability of various food animals, "availability" being the proportion of the population which in a typical habitat would be visible to a fish of the type under consideration, and of suitable size and flavour to be eaten by it.

Among the most important food animals is *Gammarus lacustris*, which constitutes the major food item of both trout and char, especially of char in

winter and spring. Trichoptera larvae constitute the major food of trout at all seasons. Chironomid larvae, the most abundant of all bottom animals, provide an important source of food for trout and char in winter.

Having defined the various terms used, the author discusses the competition trout and char have to face, and the ecological niches they occupy. From the investigations carried out it appears that in lakes inhabited by both species, the fish occupy well defined ecological niches. During the time when bottom food suitable for both species is least abundant, the char turns to the open waters to feed on plankton. Thus it seems that the limits of the niches are surpassed when food such as *Gammarus*, which is tempting to both species, becomes superabundant for a time. It also appears that planktonic crustaceans and open water provide optimal conditions for char species in relation to competing trout species. However, the low growth-rate of the char may be compensated for by a numerous population, which can compete successfully with the less numerous trout population. When more of the larger food items are available to char, without competition, they turn to them and increase in size and condition.

An interesting situation occurs in Korsvattnet, which does not contain trout. There are two forms of char in this lake, the so-called "big char" with a very rapid growth-rate, and "dwarf char" with a very slow growth-rate. The feeding behaviour of the "dwarf char" is characterized by a very extensive consumption of crustacean plankton, and can be compared with that of the char of Blåsjön, whereas the "big char" seem to correspond to the trout of Blåsjön.

The paper contains references to published and unpublished works of previous investigators, and is profusely illustrated with tables and graphs.

A. Swain

G. Svärdson. "Salmon stock fluctuations in the Baltic Sea". Rep. Inst. Freshw. Res., Drottningholm, 36, pp. 226–62, 5 figs. Lund, 1955.

The salmon of the Baltic Sea constitute a virtually isolated group, sensitive only to conditions within the Baltic area. Records of catches have been studied with a view to correlating the variations in the catches with recognizable controlling factors, and evidence of climatic effect is adduced from the fact that catches outside the Baltic varied sympathetically with those inside. The falls in the local catches in the 1890s, and the rise since 1940, however, are not reflected outside, and indicate that the factors responsible are local.

Recently a statistical connexion has been demonstrated between the salmon catch and the extent of the winter ice-cover in the Baltic. The catch reaches a maximum five years after the maximum in the ice-cover, and therefore the fish caught represent the generation succeeding that which experienced the greater extent of freezing.

In the light of climatic effects, the author discusses the parr-smolt transformation; he ascribes this to the interaction of a photoperiodic sensitivity with age and with temperature changes. It occurs later in the northern than in southern rivers, and tables of the smolt ages and temperatures for several

rivers are given to illustrate this. The trend is not surprising, in view of the influence of temperature on feeding habits and the availability of food.

The author considers that the high smolt age and delayed maturity of the northern salmon result from a feeble environmental stimulus, and examines the situation in the Baltic at some length. The temperature of the sea water in spring depends largely on the preceding winter temperature; the colder the winter, the longer the sea takes to warm. The growth of salmon at sea is particularly affected by the temperatures in spring and early summer; consequently a smolt delayed in its first year by cold has proportionately less time at sea in its first summer, and experiences less favourable conditions, than the smolts of an early season. When a warm spring follows a cold one, some telescoping of the catches from successive year-classes is therefore to be expected; the growth of the one class will have been delayed, whilst that of the next is accelerated, so that they tend to mature together.

In the second part of the paper, the effects of predation are considered. It is generally agreed that the maximum danger falls in the early stages both of river and sea life; the smaller a fish is, the greater the proportion of other creatures which are capable of eating it. It follows that the more rapid the growth, the less the loss from predation.

In the fluvial phase, goosanders and mergansers are the worst predators; their feeding habits are discussed in another paper in the present volume, in which it is calculated that a hundred birds could clear the smolt population of a stream during the season. Control of these birds has been found most efficacious in Canada, where a ninefold increase in smolt production followed, but their influence on the salmon stock of a river must depend on the relative abundance of salmon parr among other fishes. In Great Britain the birds are relatively rare, and in England they are protected.

Predation at sea is ascribed to seals and porpoises. Predation by fish is not considered, though in English waters skate are to be found actively feeding on sprats off the river mouths at the time of smolt migration, and it seems unlikely that the smolts are immune.

The grey seal is regarded as the most serious menace to the salmon, largely as a result of its habit of plundering nets, which always attracts a somewhat disproportionate degree of notice. In the Baltic its depredations are limited by the winter conditions; only the ringed seal keeps a hole open through the ice, and a hard winter is therefore unfavourable to the grey and harbour seals.

Porpoises normally migrate from the Baltic for the winter. These creatures suffer heavily when the sea freezes, and this encourages the belief that the hazard which they constitute to the salmon stock is a major one, and one which is mitigated by a severe winter. This view is reinforced by the evidence that periods when porpoise hunting has been practised in the Sounds coincide with increased salmon catches in the Baltic, and the author suggests that hunting should be intensified, in the hope that it will prove to be beneficial.

W. G. Hartley

H. B. Bigelow and **W. C. Schroeder.** "Fishes of the western North Atlantic. Sawfishes, guitarfishes, skates and rays. Chimaeroids". Sears Foundation for Marine Research, Mem., 1, Pt. 2, XIV + 588 pp., 127 figs. New Haven, Conn., 1953.

Part One of "Fishes of the North Atlantic", which deals with lancelets, Cyclostomes, and sharks and was written for the most part by the two authors of Part Two, appeared in 1948, and was reviewed in the *Journal du Conseil*, Vol. XVI, pp. 397–98, 1950.

The authors set a very high standard in Part One, and it is gratifying to be able to state that Part Two is in every way as good as Part One. It has now come to be regarded as indispensable to any ichthyological library. There are the same careful descriptions and the excellent figures are supported by detailed information, some of which is quoted from the literature, while in other places it is original. Reproduction, life-habits, distribution, etc. are discussed.

MERRIMAN, OLSEN, WHEATLAND, and CALHOUN are the authors of a seven-page addendum in which they summarize their study of the life-history of *Raja erinacea*.

The identification of several of the rarer skates and rays has often been difficult, especially at sea. Now the biologists have a tool which will enable them to identify the species with confidence, the first all-important step in biological studies.

In a more general way it is fascinating to read in this volume of the giant devil-fishes, the pygmy *Breviraja* species (of which BIGELOW and SCHROEDER have described 6 species out of the 7 mentioned), the fantastic sawfishes, the electric rays, and — last but not least — the chimaeroids, which in many ways are just as interesting survivors from remote ages as the coelacanths.

BIGELOW and SCHROEDER have again produced a book which will be reckoned amongst the masterpieces of ichthyological literature.

Anton Fr. Bruun

R. G. Lindberg. "Growth, population dynamics, and field behavior in the spiny lobster, *Panulirus interruptus* (RANDALL)". Univ. California, Publ. Zool., **59**, 6, pp. 157–248, 16 figs., 7 pl. Berkeley & Los Angeles, 1955.

Investigation of the larger crustacea is circumscribed by the selectivity of the sampling gear available. An account based on data both from normal commercial trapping and from diving operations is, therefore, particularly useful. The species investigated is the spiny lobster, *Panulirus interruptus*. As its characteristics are to a large extent common to a number of important species, the results assume a wider significance. Because of this, greater emphasis might perhaps have been placed on comparing the results obtained from the two sampling methods.

Except for one station, the diving operations at all seasons, were carried out in an area of about 40 square miles, covering varying types of habitat, and including both commercially exploited and protected grounds. Trapping for the most part followed normal commercial practice. Underwater

observations showed that insecure or faultily grounded traps and poor siting resulted in a marked variation of the catch by individual pots. Similarly the catch by individual traps or only a few traps did not always appear to reflect the local abundance of lobsters. This result was to be expected, but it does not necessarily invalidate estimations of stock density based on the catches of a large number of traps fished over a period. Further investigation of the causes underlying disparity between trap yields and lobster abundance would be useful.

The population is shown to be relatively sedentary and confined to rocky bottoms, the lobsters undertaking local foraging expeditions mainly at night. However, they do change grounds to avoid surge and turbid water as well as other unfavourable conditions. Apart from such excursions, movement is normally restricted by natural barriers such as green mud, open sand, or deep channels with strong currents. The local distribution is very irregular, the lobster seeking holes or crevices and showing preference for the sheltered sides of reefs, etc. This factor is in part responsible for differences between catches in traps almost adjacent to one another.

Panulirus interruptus is a scavenger, attracted to its food by both sight and smell. Stomach analyses of material taken by diving show a wide variety of food organisms, the commonest being sabellids, but the primary factor in deciding what food is taken is availability. The predators of lobsters also tend to vary in importance locally. It appears that lobsters are unaware of their potential predators except when these are actively moving.

Panulirus does not undertake extensive migrations along the shore, but the concentration of marketable lobsters in shallow water is greatest from April to August. On the other hand, "short" lobsters seemed to be present in the same concentration all through the year. The author suggests that there is a movement on and off shore associated with sexually mature individuals. However, the observed variations may result indirectly from fishing practice, at least in part.

Moulting lobsters are not caught in traps. They take cover and were therefore also not caught in any appreciable quantities by diving. Other data presented suggest that mature female lobsters cast at least annually and carry spawn each year. The eggs have an incubation period of nine to ten weeks, incubation taking place mainly during April to August. Male lobsters moult twice annually. It is stated that observations on "mature lobsters suggest an annual growth of approximately 3 cm." It would appear that this is considered to apply to both sexes irrespective of spawning. Fifty per cent. of female lobsters of 21 cm. and ninety per cent. at 23·5 cm. overall length were found to be sexually mature. Males mature at a slightly smaller size.

The behaviour of the animal in natural surroundings, its methods of locomotion, and its reaction to enemies and food are described. The paper treats the species from the aspect of the fishery as well as its biology. The author suggests that a minimum legal landing size of 21·4 cm. overall length would be more realistic than the present limit of 26·6 cm.

H. J. T.

Current Bibliography

Prepared by the Editor with the Assistance of Mr. A. R. Margetts

Note. The scope of the Bibliography is limited in the main to the area covered by the Council's activities, but there are included papers of general interest relating to other areas in North Temperate and Arctic regions and exceptionally elsewhere. Limnological references are not as a rule given, but papers relating to brackish waters and to salmon and freshwater fish studied by the Council are included.

Subscribers and those on the distribution list will receive regularly upon application to the General Secretary copies of the Bibliography printed on one side of the page only, for use in making up card indices.

The Editor will be glad to be advised of emendations and additions to the Bibliography.

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